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ENGINEERING

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXVIII.

JANUARY TO DECEMBER, 1902.

NEW YORK:

PUBLISHED BY THE SOCIETY.

1902.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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PROCEEDINGS

OF THE

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(INSTITUTED 1852.)

VOL. XXVIII. No. 1.
JANUARY, 1902.

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS.

NEW YORK 1902.

American Society of Civil Engineers.

OFFICERS FOR 1901.

President, ROBERT MOORE.

Vice-Presidents.

Term expires January, 1903:	*Term expires January, 1904:*
HENRY S. HAINES,	CHARLES C. SCHNEIDER.
GEORGE H. BENZENBERG,	JOHN R. FREEMAN,

Secretary, CHARLES WARREN HUNT.

Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1903:	*Term expires January, 1904:*	*Term expires January, 1905:*
JOHN F. O'ROURKE,	JOSIAH A. BRIGGS,	RICHARD S. BUCK,
HENRY B. SEAMAN,	GEORGE F. SWAIN,	GEORGE H. PEGRAM,
THOMAS H. JOHNSON,	EMIL KUICHLING,	WILLIAM J. WILGUS,
JOSEPH RAMSEY, JR.,	MORDECAI T. ENDICOTT,	WILLIAM JACKSON,
HENRY B. RICHARDSON,	EDWARD C. CARTER,	EDMUND F. VAN HOESEN,
WILLIAM H. KENNEDY,	FRANK C. OSBORN.	JAMES L. FRAZIER.

Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:	*On Publications:*	*On Library:*
JOSIAH A. BRIGGS,	JOHN F. O'ROURKE,	H. S. HAINES,
G. H. BENZENBERG,	GEORGE H. PEGRAM,	CHARLES C. SCHNEIDER,
GEORGE F. SWAIN.	THOMAS H. JOHNSON,	M. T. ENDICOTT,
RICHARD S. BUCK,	JOSEPH RAMSEY, JR.,	E. KUICHLING,
WILLIAM J. WILGUS,	FRANK C. OSBORN,	CHARLES WARREN HUNT.

Special Committees.

ON ANALYSIS OF IRON AND STEEL:—Sub-Committee of the American Society of Civil Engineers (of the International Committee on Standards for the Analysis of Iron and Steel, of which Prof. J. W. Langley is Chairman)—Charles B. Dudley, William Metcalf, Thomas Rodd.

ON UNITS OF MEASUREMENT:—George M. Bond, William M. Black, R. E. McMath, Charles B. Dudley, Alexander C. Humphreys.

ON THE PROPER MANIPULATION OF TESTS OF CEMENT:—George F. Swain, Alfred Noble, George S. Webster, W. B. W. Howe, Louis C. Sabin, S. B. Newberry, Clifford Richardson, Richard L. Humphrey, F. H. Lewis.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - - 583 Columbus.
CABLE ADDRESS, - - "Ceas, New York."

Vol. XXVIII. JANUARY, 1902. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

January 8th, 1902.—The meeting was called to order at 8.40 P. M., President J. James R. Croes in the chair; Charles Warren Hunt, Secretary; and present, also, 66 members and 7 guests.

The minutes of the meetings of December 4th and 18th, 1901, were approved as printed in the *Proceedings* for December, 1901.

A paper by Elnathan Sweet, M. Am. Soc. C. E., entitled "Some Important Phases of Canal Navigation, Illustrated by Recent Experiments in Germany;" was presented by the Secretary.

There being no discussion on the paper, the President called upon Mr. George W. Fuller to give his impressions of Mexico, which he had recently visited, and at the conclusion of Mr. Fuller's interesting remarks Messrs. W. H. Wiley and George A. Soper supplemented them by statements of personal experience in that country.

Ballots were canvassed and the following candidates declared elected:

As Members.

William Davis Barber, Chicago, Ill.
Chokuro Kadono, Tokyo, Japan.
David Simson, Buenos Aires, Argentine Republic.

As Associate Members.

Julian Du Bois, Amsterdam, N. Y.
Edward Bayrd Fay, St. Louis, Mo.
John Flynn, Jr., Troy, N. Y.
Edwin Grant Lane, Cleveland, Ohio.
Ralph Eells Newton, Milwaukee, Wis.
Clarence Du Bois Pollock, New York City.
William Stuart Smith, Rochester, N. Y.
George Eber Stratton, Boston, Mass.
Charles Eliphalet Trout, New York City.

The Secretary announced the election of the following candidates by the Board of Direction on January 7th, 1902:

As Associates.

Leslie J. Bennett, Buffalo, N. Y.
Charles Francis Asa Hennessey, New York City.

As Juniors.

Robert Henry Hammer, Brooklyn, N. Y.
Harry Garfield Harrington, Newark, N. J.
Abraham Underhill Whitson, College Point, N. Y.
Frederick Wilcock, Brooklyn, N. Y.
Philip Harold Winchester, Watertown, N. Y.

The Secretary announced the death of Thomas Crabb, elected Junior April 4th, 1899; died December 21st, 1901.

The Secretary reported that the ballot on the appointment of a Special Committee on Rail Sections had been canvassed by the Board of Direction. at its meeting on January 7th, 1902, with the following result:

Total ballots received		1 098
Without signature	14	
Not entitled to vote	10	
Otherwise defective	18	
		42
Total votes counted		1 056
Voted "yes"	1 014	
Voted "no"	42	
		1 056

And, inasmuch as the corporate membership on January 7th, 1902, was 2 122, the vote complies with the constitutional provision, and the Committee will be appointed by the Board.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

January 7th, 1902, 8.10 P. M.—President Croes in the Chair; Charles Warren Hunt, Secretary; and present, also, Messrs. Bensel, Briggs, Buchholz, Haines, Hering, Knap, Kuichling, Seaman and Turner.

A payment of $5 000 on the principal of the mortgage indebtedness of the Society was ordered.

The Annual Report of the Board of Direction for the year ending December 31st, 1901, was adopted.

Ballots on the appointment of a Special Committee to report on Standard Rail Sections were canvassed, with the result that the ballot was decided in the affirmative.*

The appointment of the Special Committee was made a special order for business for the February meeting of the Board.

The following resignations were accepted, taking effect December 31st, 1901.

Malcolm Scollay Greenough, William Louis Marshall, Henry Thompson Douglas, Samuel Hosmer Chittenden, Clifford Stephen Kelsey.

A report was received from the Committee appointed to recommend the award of prizes for the year ending with the month of July, 1901, and the following awards were made by the Board:

The Thomas Fitch Rowland Prize was awarded to Paper No. 881, entitled, "The Ninety-sixth Street Power Station of the Metropolitan Street Railway Company, of New York City," by L. G. Montony, Assoc. M. Am. Soc. C. E.

The Collingwood Prize for Juniors was awarded to Paper No. 883, entitled, "A Proposed Method for the Preservation of Timber," by F. A. Kummer, Jun. Am. Soc. C. E.

It was further resolved that no award of the Norman Medal be made for the year ending with the month of July, 1901.

Applications were considered and other routine business transacted.

Two candidates for Associate and five for Junior were elected.*

Adjourned.

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* See page 2.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, February 5th, 1902.—8.30 P. M.—At this meeting ballots for membership will be canvassed, and a paper by Ernest P. Goodrich, Jun. Am. Soc. C. E., entitled "The Supporting Power of Piles," will be presented for discussion.

This paper was printed in the *Proceedings* for December, 1901.

Wednesday, February 19th, 1902.—8.30 P. M.—At this meeting a paper by Walter Loring Webb, Assoc. M. Am. Soc. C. E., entitled "Some Devices for Increasing the Accuracy or Rapidity of Surveying Operations," will be presented for discussion.

This paper was printed in the *Proceedings* for December, 1901.

Wednesday, March 5th, 1902.—8.30 P. M.—At this meeting ballots for membership will be canvassed, and a paper by George S. Morison, Past-President, Am. Soc. C. E., entitled "The Bohio Dam," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

Wednesday, March 19th, 1902.—8.30 P. M.—At this meeting a paper by C. A. P. Turner, M. Am. Soc. C. E., entitled "Thermo-Electric Measurement of Stress," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL CONVENTION OF 1902.

The Thirty-fourth Annual Convention of the Society will be held at Washington, D. C., beginning on Tuesday, May 20th, 1902.

ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING DECEMBER 31st, 1901.

Presented at the Annual Meeting, January 15th, 1902.

The Board of Direction, in compliance with the Constitution of the Society, presents its report for the year ending December 31st, 1901.

MEMBERSHIP.

The changes in membership are shown in the following table:

	Jan. 1st, 1901.			Jan. 1st, 1902			Losses.				Additions.		Totals	
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	Transfer.	Resignation.	Dropped.	Death.	Transfer.	Election.	Loss.	Gain.
Honorary Members......	1	8	9	2	8	10	..	..	....	....	1	....	....	1
Corresponding Members	....	3	3	....	2	2	1	..	....	....	....	....	1	...
Members................	280	1 140	1 420	286	1 222	1 508	..	7	7	24	*38	88	38	126
Associate Members......	142	374	516	161	451	612	34	1	1	2	†36	98	38	134
Associates..............	36	65	101	38	73	111	1	..	....	2	‡1	12	3	13
Juniors.................	99	152	251	101	150	251	40	1	20	1	....	62	62	62
Fellows.................	9	28	37	9	25	34	..	..	....	3	....	....	3	...
Totals..............	567	1 770	2 337	597	1 931	2 528	76	9	28	32	76	260	145	336

* 34 Associate Members and 4 Juniors.
† 1 Associate and 35 Juniors.
‡ 1 Junior.

The net increase during the year, as shown by the above table, was 191, and it may be of interest in this connection, to give from the records the yearly rate of increase in the total membership.

At the end of 1869 the total membership was 160, and, omitting the class of "Subscribers," which was created in 1882, but does not exist under the present Constitution, the net yearly increase has been as follows:

Year.	Increase.	Year.	Increase.	Year.	Increase.	Year.	Increase.
1870	83	1880	10	1890	111	1900	138
1871	36	1881	46	1891	91	1901	191
1872	58	1882	62	1892	111		
1873	77	1883	37	1893	89		
1874	31	1884	82	1894	75		
1875	47	1985	50	1895	114		
1876	60	1886	91	1896	99		
1877	22	1887	91	1897	63		
1878	19	1888	133	1898	47		
1879	8	1889	93	1899	103		

The total increase	in the	ten	years	1870–9	was	441,	an average	of	44.1
"	"	"	"	1880–9	"	695	"	"	69.5
"	"	"	"	1890–9	"	903	"	"	90.3
"	"	"	two years	1900–1	"	329	"	"	164.5

It will be noticed that up to 1899 no two consecutive years have shown an increase of 100, but that the increase for each of the past three years has been more than 100, which indicates that the present rate of increase is not a spasmodic one due to temporary conditions.

The total number of applications received during the year was 375.

Action taken by the Board has been as follows:

Passed to ballot as Members	129
Passed to ballot as Associate Members	134
Elected Associates	13
Elected Juniors	66
Total	342
Applications now awaiting action	78

The amount of work demanded in connection with 375 applications, in addition to ordinary correspondence, is very great, as it involves the briefing and typewriting of 2 500 copies of individual records, the forwarding of 10 000 circulars and blanks, and the collation and tabulation for the use of the Board of 2 000 answers from endorsers.

Some idea of the volume of printed matter which it is necessary to issue, under the rules, may be gathered from the following figures for 1901, and it should be remembered that all of this must be prepared with great care from original manuscript applications, which, in form, differ greatly from one another:

	Pages.	No. of words.
10 Blue Lists	118	88 500
10 Ballot Lists	92	69 000
Reconsideration Notices	7	5 250
" Ballots	7	5 250
Total issues	224	168 000

This is equivalent to 375 pages, or nearly a volume, of *Transactions*.

In its last Annual Report the Board called the attention of members to the care with which all applications are scrutinized, and to the weight which the Board gives to confidential communications in regard to candidates. It is desired now to emphasize what was there said as

to the best method of preventing the election of an undesirable person, viz., that each member, upon receipt of the Blue List, should forward to the Board any information concerning a candidate which bears upon his eligibility. This would prevent the appearance of the name of an undesirable candidate upon the Ballot List, and would do away with the necessity for a negative ballot.

The losses by death reported during the year number 32. They are as follows:

Members: Charles Kimball Bannister, Daniel P. Bruner, Thomas Curtis Clarke, Henry St. Leger Coppée, John Hislop, George Washington Howell, William Rich Hutton, Andrew Langstaff Johnston, William Bateman Lawson, Trevor McClurg Leutzé, William Ludlow, Thomas Speer McNair, Niles Meriwether, Alfred Petry, George Austin Quinlan, Thomas Laidlaw Raymond, Benjamin Reece, Richard Pennefather Rothwell, George McCracken Rusling, Robert Imlay Sloan, John Larkin Thorndike, Ashley Bemis Tower, Lebbeus Baldwin Ward, Nelson Oliver Whitney.

Associate Members: Paul David Cunningham, Levis Passmore Pennypacker.

Associates: Henry Robert Bradbury, James Frederick Lewis.

Junior: Thomas Crabb.

Fellows: James Goodwin Batterson, Albert Conro, Stephen Paschall Morris Tasker.

LIBRARY.

The growth of the Library during the past year has been quite in keeping with the phenomenal increase in the membership. This growth has been due in part to the stimulating effect of the issue of the Catalogue of the Library in the latter part of 1900, and also to special and systematic efforts to complete files of reports and of both foreign and home periodicals, and to the purchase of current textbooks and engineering works in English, German and French. Special donations received through publishers, notices of which have been issued in each monthly number of *Proceedings*, have also helped to swell the list, and a large and valuable bequest from the library of the late Henry B. Hammond was also received.

This increase in accessions has added greatly to the routine library work. The labor and time necessary to enter into correspondence with Railroad Companies, Municipalities, Authors and Publishers and to prepare book notices, catalogue each accession, and prepare and keep up to date copy for subsequent issues of the Library Catalogue has been large; but the Board believes the results obtained, which have been indicated in detail in the monthly *Proceedings*, and are summed up in the comparative statement which follows, have justified the additional expense incurred.

Accessions During the Year 1901.

	Bound Volumes.	Unbound Volumes.	Specifications.	Maps, Photos, Charts, etc.	Total.
Donations—Traceable to Library Catalogue.......	88	392	....	1	481
" In answer to special requests	57	2 166	....	....	2 223
" From Publishers...	39	9	....	....	48
" Hammond Bequest..	203	742	4	....	949
" In Regular Course..	250	591	103	118	1 062
Exchange of Duplicates........	43	1 080	....	....	1 123
By Purchase.......	124	16	....	1	141
Totals.................	804	4 996	107	120	6 027

In addition to the above, there have been received about 800 duplicates and 161 separate numbers to complete files of periodicals, neither of which can appear as accessions.

The yearly accessions during the last six years are given in the following table, which shows that in 1901 there were 532 more accessions than were received in the whole previous five-year period:

Year.	Bound Vols.	Unbound Vols.	Specifications.	Maps, Photos, Charts, etc.	Total.
1896......	188	630	26	234	1 078
1897......	323	559	122	176	1 180
1898......	197	749	285	9	1 240
1899......	268	375	297	36	976
1900......	281	359	254	127	1 021
1901......	804	4 996	107	120	6 027

The Library now contains—

Bound Volumes..............................	9 612
Unbound Volumes.............................	25 243
Specifications..................................	2 563
Maps, Photographs, Charts, etc.................	2 693
Total..................................	40 111

The total number of titles in the Library is 18 201.

During the year a careful inspection of some 3 400, more or less complete, volumes of unbound periodicals was made, and the binding of about 1 100 volumes has been undertaken.

To date, 414 of these have been bound and are now on our shelves in accessible and durable form. It is the intention of the Board to

continue this work, in the belief that it is wise to preserve in a reference library, in the most convenient and accessible form, sets of such periodical literature as may be called for, even though references to them are somewhat infrequent.

Since the publication of the Library Catalogue, the Secretary has received from non-resident members quite a number of requests for information concerning engineering references along special lines, and special searches have been made covering these subjects. Typewritten lists of references to the books and periodicals in the Library have been furnished, and these bibliographies have evidently been of much benefit to members.

The Board believes that if the Membership understood that these searches would be made upon request, many would avail themselves of this source of information.

The furnishing of such information involves a considerable expenditure of time on the part of the employees of the Society qualified to collate the special data asked for by individual members, to the exclusion of the prosecution of their ordinary labors, which, while in the same direction, are devoted to the general advantage of the membership.

It has seemed proper, therefore, to the Board, to require that the actual amount of the expenditure incurred in the collation of special information for an individual should be paid for by the applicant for such information. The Secretary, accordingly, has been directed to charge for and collect from members and others to whom special information, which involves research and correspondence not falling within the regular duties of employees of the Society, may be furnished, the actual cost of the extra work necessary to reply to their requisitions.

The following gives the amount expended upon the Library during the year:

Purchase of Books (124 Volumes)	$363.98
Expressage, etc	47.61
Binding (414 Volumes)	378.72
Fixtures and Supplies	78.45
Total	$868.76

The value of the accessions to the Library during the year is as follows, each accession having been valued separately, as received:

	5 886 Donations and Exchanges (estimated value)	$2 704.38
	141 Purchase (cost)	363.98
Total	6 027	$3 068.36

PUBLICATIONS.

During the year the usual ten numbers of *Proceedings* and two volumes of *Transactions* have been published, the total number of pages in these publications showing a slight increase over the same publications for last year.

In the last annual report the Board stated that the Secretary had been authorized to prepare a General Index to *Transactions*. During the year this work, which involved the indexing of forty-five volumes, covering 23 370 pages, was completed, and published in September in a separate volume of 244 pages, a copy of which was furnished to each person connected with the Society. This work was performed by the Secretary and the regular office force, in addition to regular duties.

The publication of this Index makes possible the following statement, which would appear to be of interest, the question having often been asked as to the interest taken in the publications by the membership at large.

Of the total living membership of the Society in all grades, it is found that 12% have contributed papers, and that 27% have contributed either papers or discussions, or both.

With a view of ascertaining the effect of the present method of publication on the technical output of the Society the table given below has been prepared.

Period.	Number of volumes.	Total pages.	Papers.		Discussions.		Memoirs.	Average Length, in Pages.		Number of discussions per paper.
			Number.	Total pages.	Number.	Total pages.	Total pages.	Papers.	Discussions.	
1872-1877..	6	2 391	152	1 974	278	423	—	13	1.52	1.82
1878-1883..	6	2 570	119	1 934	240	636	—	16.25	2.65	2.01
1884-1889..	9	4 233	159	2 886	609	1 347	—	18.15	2.21	3.83
1890-1895..	13	7 728	339	5 185	1 331	2 537	—	15.29	1.9	3.92
1896-1901..	12	7 020	141	3 410	1 088	3 332	278*	24.18	3.06	7.72
Total and average.	46	23 942	910	15 389	3 546	8 275	278	16.9	2.33	3.90

*Before this period, Memoirs were not published in *Transactions*.

It will be seen that the publications of the Society have been divided into periods of six years each, in the earliest of which no advance copies of papers were issued. From June, 1879, to December, 1895, a few advance copies of papers were printed and sent to members specially selected by the Secretary for the purpose, with a request for

discussion, and, in addition to this, from April, 1892, to the end of 1895 semi-monthly bulletins, containing abstracts of papers to be presented, were regularly issued. During the last six years, all papers have been published in *Proceedings* in advance of the date set for their presentation, and nearly always sufficiently in advance of that date to enable distant members to be represented at the meetings by discussion in writing if they so desired.

During this last period, the amount of output under the several headings, in percentages of the whole, is as follows:

Percentage of the entire time during which publications of the Society have been issued	16.67
" " Total Volumes	26.1
" " " Pages	29.3
" " " Number of Papers	15.5
" " " Pages of Papers	22.1
" " " Number of Discussions	30.7
" " " Pages of Discussion	40.3

The figures showing the average length of papers and discussions, and the number of discussions per paper, are perhaps the most significant and interesting, as they indicate, during this last period, a much wider and more carefully prepared discussion than obtained under the old system, and the increase under these headings over the previous average is:

In length of papers	55.2 per cent.
" " " discussions	52.4 "
In number of discussions per paper	141.2 "

The amount of matter in type at the present time is such that it has been decided to publish three volumes during 1902, the first of which will be ready for distribution about April, 1902.

In the *Proceedings* the list of references to current engineering literature (begun in March, 1899) has been regularly kept up, and, during the year, has covered 69 pages, containing 3 161 classified references to 54 periodicals. These references have been collated in scrap books under each of the classified headings, and are thus preserved in the Library for convenient reference.

During the year additional shelving was erected, and the stock of extra numbers of papers, monthly *Transactions* and *Proceedings*, and volumes of *Transactions*, has been carefully inventoried, and stored permanently in accessible form. The cost of each to the Society has

also been determined, and it is found that the Society now has in stock 119 108 copies of its various publications, the actual cost of which has been $13 931.10. This stock, which is kept for the convenience of members and others, is being largely added to, each year.

Owing to the increase in the number of members who have their volumes of *Transactions* bound in standard style, it has been possible to effect a considerable reduction in the cost of this binding, and this reduced cost has already gone into effect with the binding of Vol. XLVI, the reduction being from $1.20 to $1.00 for half morocco, and from 75 cents to 50 cents for cloth bindings.

SUMMARY OF PUBLICATIONS FOR 1901.

	Number Issued.	Total Edition of each.	Number of Pages.	Plates.	Cuts.
*Transactions**	2	2 700	1 245	24	182
*Proceedings**	10	2 850	1 485	25	245
Constitution and List of Members	1	3 000	222	..	...
Advertisements	10	2 850	144	..	...
Index to *Transactions*, Vols. I to XLV	1	3 000	244	..	...
Totals	..	....	3 340	49	427

The cost of Publications has been:

For Paper, Printing, Binding, etc., *Transactions* and *Proceedings*		$7 950.54
For Plates and Cuts		1 087.34
For Boxes, Mailing Lists, Copyright, and Sundry Expenses.		182.25
For Commission on Advertisements		327.67
For 8 525 copies of Papers and Memoirs		550.09
For List of Members		818.64
For Index to Transactions, Vol. I to XLV		650.89
Total		$11 567.42
Deduct amount received for advertisements	$2 010.00	
Deduct amount received for sale of publications	2 392.08	
		4 402.08
Net cost of Publications for 1901		$7 165.34

* Includes Indexes and Tables of Contents.

MEETINGS.

During the year 24 meetings have been held, as follows: At the Annual Meeting, 2; at the Annual Convention, 4; regular semi-monthly meetings, 18.

At these meetings 15 formal papers, 3 of which were illustrated with lantern slides, 5 topics for informal discussion, and 5 illustrated lectures, were presented.

The Thirty-third Annual Convention was held at the International Hotel, Niagara Falls, N. Y. There were registered at this convention 317 members of the Society, in all grades, accompanied by 311 members of their families.

MEDALS AND PRIZES.

For the year ending with the month of July, 1900, Medals and Prizes were awarded as follows:

The Norman Medal, to James A. Seddon, M. Am. Soc. C. E., for his paper on "River Hydraulics."

The Thomas Fitch Rowland Prize, to Allen Hazen, M. Am. Soc. C. E., for his paper entitled "The Albany Water Filtration Plant."

The Collingwood Prize for Juniors, to Robert P. Woods, Jun. Am. Soc. C. E. (now Assoc. M. Am. Soc. C. E.), for his paper entitled "Street Grades and Cross-Sections in Asphalt and Cement."

FINANCES.

An examination of the Secretary's Statement of Receipts and Disbursements, and of the General Balance Sheet, which accompanies it, shows that, although much additional work has been performed by the office force, as has already been pointed out, the work has been done in an economical manner.

A payment of $5 000 on the principal of the mortgage indebtedness was made, and an additional payment of $5 000 has been ordered in 1902. These two payments, which carry out the recommendation of the Board of January, 1900, that a sum approximately equal to the amount of Entrance Fees received each year be applied to extinguishing the debt, will bring the amount paid for this purpose during three years to $20 000, and reduce the debt to $65 000.

CONCLUSION.

The condition of the Society, at the beginning of its fiftieth year of existence, shows that it has been successful in the accomplishment of the purposes for which it was organized, as set forth by its founders.

These objects, as stated in the Constitution, are: "The advancement of engineering knowledge and practice, and the maintenance of a high professional standard among its members."

How the "means to be employed for this purpose" have been strengthened during recent years, has been set forth annually in the reports of the Board. The progress made in the holding of regular and successful "meetings for the presentation and discussion of appropriate papers, and for social and professional intercourse;" in the "publication of such papers and discussions as may be expedient"; and in "the maintenance of a library, the collection of maps, drawings and models, and the establishment of facilities for their use" seems to be gratifying and satisfactory.

The Society House, which has now been occupied for more than four years, has proved to be adequate in size and convenient in arrangement for carrying on the increasing work, and the provision made for future expansion seems to be ample for many years to come.

In view of the large number of elections during the past year, and the increasing ratio of yearly additions to the total membership, it seems proper to emphasize the fact that this is not the result of any change in the requirements for admission, but is, on the contrary, in spite of the maintenance of a higher standard of eligibility, and the most careful scrutiny of the qualifications of each candidate.

The Reports of the Secretary and the Treasurer are appended.

By order of the Board,

CHAS. WARREN HUNT,
Secretary.

NEW YORK, January 7th, 1902.

GENERAL BALANCE SHEET, DECEMBER 31st, 1901.

ACCOMPANYING REPORT OF THE SECRETARY.

ASSETS.			LIABILITIES.	
Building and Lot (cost)		$191 730.26	Dues for 1902, paid in advance	$10 548.83
Furniture (cost)		15 303.96	Mortgage Debt	70 000.00
Publications on hand; inventoried value		13 931.10	*Funds invested in Society House and Lot, and Library	205 100.15
Library:				
Cash expended for Books, etc.	$5 668.76			
Estimated Value of Donations	37 778.32	43 447.08		
Due from Members	$3 804.26			
" " Non-Members, for Publications	596.51			
" for Advertising	842.50	5 243.27		
Cash		15 993.31		
		$285 648.98		$285 648.98

*These funds have been derived from the following sources:

Norman Medal Fund	$1 000.00
Rowland Prize Fund	1 222.50
Collingwood Prize Fund	1 000.00
Donations to Building Funds	45 479.50
Profit on 23d St. House and on Securities	20 319.92
Profit on sale of Historical Sketch	1 498.06
Income Account	76 328.57
McCrea Swift Fund	1 000.00
Fellowship Fund	13 068.28
Compounding Dues Fund	6 440.00
Donations to Library, valued at	37 778.32
	$205 100.15

The Norman Medal, Rowland Prize and Collingwood Prize Funds no longer exist as such; the obligations under them having been assumed by the Society, with the consent of the donors.

REPORT OF THE SECRETARY, FOR THE

To the Board of Direction of the

Gentlemen,—I have the honor to present a statement of Re-
December 31st, 1901. There is also presented a general balance sheet
New York, January 7th, 1902.

Receipts.

Balance on hand December 31st, 1901, in Bank and Trust Company and in hands of the Treasurer		$9 929.82
Entrance Fees	$6 595.00	
Current Dues	28 722.93	
Past Dues	1 191.22	
Advance Dues	10 548.83	
Certificates of Membership	254.45	
Badges	1 117.50	
Sales of Publications	2 391.58	
Advertisements	2 010.00	
Interest	157.82	
Compounding Dues	575.00	
Library	6.00	
Convention	275.00	
Annual Meeting	854.00	
Binding	1 745.00	
Miscellaneous	51.46	
Historical Sketch	5.00	
		56 500.79
		$66 430.61

YEAR ENDING DECEMBER 31ST, 1901.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

ceipts and Disbursements for the fiscal year of the Society, ending showing the condition of the affairs of the Society.

Respectfully submitted,

CHAS. WARREN HUNT,

Secretary.

DISBURSEMENTS.

Salaries of Officers	$8 199.96	
Clerical Help	7 822.93	
Caretaking	1 417.53	
Publications	11 372.24	
Postage	2 817.97	
General Printing and Stationery	1 681.79	
Badges	907.40	
Certificates of Membership	127.25	
Binding	1 802.86	
Library	868.76	
Maintenance of House	156.96	
Heat, Light and Water	873.90	
Betterments	214.50	
Furniture	749.59	
Annual Meeting	1 320.57	
Convention	874.51	
Prizes	179.90	
Advertising Commission	327.67	
Interest and Insurance	3 190.00	
Petty Expenses	201.97	
Society House Loan	5 000.00	
Current Business	307.29	
Refund, Sale of Publications	21.75	
		$50 437.30
Balance on hand December 31st, 1901:		
In Union Trust Company	$7 255.06	
In Garfield National Bank	7 753.25	
In hands of Treasurer	985.00	
		15 993.31
		$66 430.61

REPORT OF THE TREASURER.

In compliance with the provision of the Constitution, the Treasurer presents the following report for the year ending December 31st, 1901:

Balance on hand December 31st, 1900			$9 929.82
Receipts from current sources January 1st to December 31st, 1901			56 500.79
Payment on audited vouchers for current business, January 1st to December 31st, 1901		$45 437.30	
Payment on principal of Bond and Mortgage		5 000.00	
Balance on hand December 31st, 1901:			
In Union Trust Company	$7 255.06		
In Garfield National Bank	7 753.25		
In hands of the Treasurer	985.00	15 993.31	
		$66 430.61	$66 430.61

Respectfully submitted,

JOSEPH M. KNAP,

Treasurer, Am. Soc. C. E.

New York, January 7th, 1902.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(December 12th, 1901, to January 7th, 1902.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Eng., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Can.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Institute, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 30c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 35c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England.
(22) *Iron and Coal Trades Review*, London, England.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, 75c.
(29) *Journal*, Society of Arts, London, England.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des Ecôle Spéciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Eng., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 75c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 10c.
(47) *Mechanical Engineer*, Manchester, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Institute of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 10c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.

LIST OF ARTICLES.

Bridge.

Notes on Protection of Metal Work of Ballasted Bridge Floors. W. H. Finley. (4) Dec.
The Interprovincial Bridge at Ottawa.* (14) Serial beginning Dec. 7, ending Dec. 14.
The Middletown (Conn.) Bridge—The Longest Highway Draw Span.* H. G. Tyrrell. (15) Dec. 27.
The Little Calumet River Drawbridge.* (14) Dec. 28.
The New East River Bridge; Its Present Condition Shown Photographically.* (20) Jan. 2.
Chicago, Milwaukee & St. Paul Bridge at Minneapolis.* (40) Jan. 3.
The Drafting Room of a Bridge Office. R. G. Manning. (14) Jan. 4. (Reprint from the *Technic*, 1900.)
Le Pont J. F. Lepine, à Paris.* J. Hervieu. (35) Serial beginning Oct., ending Dec.

Electrical.

The Bay Ridge Station of the Edison Electric Light Co. of Brooklyn.* (64) Dec.
The Crawford-Voelker Incandescent Electric Lamp. F. Z. Maguire. (26) Dec. 6.
Electricity Supply Meters. J. R. Dick. (47) Dec. 14.
The Stray Power Method of Testing Direct-Current Motors and Generators. Wm. Lincoln Smith. (27) Dec. 14.
Lighting and Railway Development on Staten Island. Max Loewenthal. (27) Dec. 28.
Alternators with Dampers. J. Fischer-Hinnen. (27) Dec. 28.
The Slaby-Arco Portable Field Equipment for Wireless Telegraphy.* A. Frederick Collins. (46) Dec. 28.
The Electric Incandescent Lamp; How It Is Made and Tested in the United States.* Bernard V. Swenson. (10) Jan.
The Economy of Isolated Electric Plants. Isaac D. Parsons. (9) Jan.
The Operation of the Rotary Converter.* David B. Rushmore. (9) Jan.
Wireless Telegraphy; Its Past and Present Status and Its Prospects.* William Maver, Jr. (10) Jan.
The New Power Station of the New York Edison Company.* (14) Jan. 4.
Moteurs et Combinateurs Électriques pour Voitures Automobiles. Joseph Rosset. (34) Serial beginning Sept., ending Dec.

Marine.

Power Consumed in Propelling the Whitehead Torpedo.* Frank M. Leavitt. (20) Dec. 12.
Battleships (of the American Navy).* (46) Dec. 14.
Monitors (of the American Navy).* (46) Dec. 14.
Latest Types of Naval Guns.* (46) Dec. 14.
Armored Cruisers (of the American Navy).* (46) Dec. 14.

Mechanical.

Compressed Air Haulage Plants. Richard Hirsch. (58) Dec.
Some Aeronautical Experiments. Wilbur Wright. (4) Dec.
Engines at the Glasgow Exhibition.* (64) Dec.
A Large Boiler Stoking Plant.* (12) Dec. 6.
Some Details of Construction in Heavy Motor Vehicles.* (47) Dec. 7.
Machine Tools and Their Use in Locomotive Works.* (12) Dec. 13.
Working Loads for Manila Rope. C. W. Hunt. (13) Dec. 12; (14) Dec. 14.
About Smoke Consumers.* D. B. Dixon. (62) Dec. 19.
The Franklin Water Tube Boiler.* (20) Dec. 19.
Stanley Works, Newark-on-Trent.* (12) Dec. 20.
Elevators for Tall Office Buildings: The Problem of Efficient Service. Reginald Pelham Bolton. (10) Jan.
Hoisting Machinery; Its Increasing Importance and Development.* Joseph Horner. (10) Jan.
A Smokeless London: The Promise of Gaseous Fuel and Electricity. W. C. Popplewell. (10) Jan.
The "Brighton" Gas Engine.* (62) Jan. 2.
Winding Field Coils from Flat Copper Strips.* (20) Jan. 2.
High Pressure Gas Lighting. W. H. Casmey. (24) Jan. 6.
Les Embrayages.* M. Euverte. (37) Nov.
Manutention Mécanique du Charbon et du Coke dans les Usines à Gaz de Dijon et du Havre.* J. Laverchère. (33) Dec. 7
La Vapeur Surchauffée et le Surchauffeur Schwoerer. (36) Dec. 10.
Les Nouveaux Laboratoires de l'École Technique Supérieure de Stuttgart.* (33) Dec. 14.
Applications Industrielles des Turbines à Vapeur Parsons.* M. Duchanoy. (33) Dec. 21.

Metallurgical.

A Japanese Copper Reduction Works.* W. L. Hildburgh. (6) Nov.
The Early History of Open-Hearth Steel Manufacture in the United States. Samuel T. Wellman, M. Am. Soc. M. E. (13) Dec. 12.
Alloys as Solutions. John Alexander Matthews. (16) Dec. 21.
Modern Iron Blast-Furnace Practice.* Frank Hearne Crockard. (9) Jan.

* Illustrated.

Military.

Late Developments in Ordnance and Armor. J. F. Meigs. (19) Dec. 14.
Range-Finders. George Forbes. (29) Dec. 20.

Mining.

The South Lesmahagow Coal-Field. J. M. Cairncross. (59) Vol. xxii, Pt. 4.
Washing of Bituminous Coals by the Luhrig Process.* J. V. Schaefer. (4) Dec.
Copper-Mining in Japan. E. W. Jardin. (16) Dec. 28.

Railroad.

The Abolition of Grade Crossings on the Providence Division of the New York, New Haven and Hartford Railroad between Boston and Dedham. Arthur S. Tuttle. (1) Nov.
Some Problems in Maintenance Arising from Rapid Increase in Air-Brake Equipment. E. M. Herr. (61) Nov.
What shall be done to Maintain theAir Brake Equipment on our Freight Cars. T. W. Demarest. (61) Nov.
Locomotive Combustion. J. W. Shepherd. (61) Nov.
The New Victoria Station at Nottingham. (11) Serial beginning Nov. 15, ending Dec. 20.
Oil Fuel for Locomotives: Practice on the Pacific Coast.* H. B. Gregg. (25) Serial beginning Dec., ending Jan.
Economy in Locomotive Service. G. R. Henderson. (15) Serial beginning Dec. 6, ending Dec. 13.
Port Richmond Terminal of the Philadelphia & Reading Ry.* (18) Dec. 14.
The Pennsylvania and Long Island R. R. Extensions across the North and East Rivers.* (13) Dec. 19.
The Player-Baldwin Oil-Burning Consolidation Locomotive—Atchison, Topeka & Santa Fe.* (15) Dec. 20.
Rail Rolling at Lower Temperatures during 1901.* S. S. Martin. (20) Dec. 26.
The Field Practice of Relining Railway Curves. Howard C. Ives. (13) Dec. 26.
New Yards and Shops of the Central Railroad of New Jersey, at Elizabethport, N. J.* (15) Serial beginning Dec. 27, ending Jan. 3.
Comparative Locomotive Tests, Michigan Central and Illinois Central Roads. (18) Dec. 28.
Vanderbilt Steel Tank Car, 12 000 Gallons Capacity.* (25) Jan.
A Brooks "Chautauqua" Type Locomotive—Central Railroad of New Jersey.* (25) Jan.; (15) Jan. 3; (18) Jan. 4.
Chautauqua Type Passenger Locomotive—Buffalo, Rochester & Pittsburg Railway.* (39) Jan.
Collinwood Roundhouse, Lake Shore & Michigan Southern Railway.* (25) Jan.
Heavy Consolidation Compound Locomotive, Atchison, Topeka & Santa Fe Railway.* (25) Jan.
Four-Cylinder Balanced Compound Locomotive: A Design by Charles M. Muchnic.* (25) Jan.
Drawing Room; Chief Engineer's Office; Pittsburg & Lake Erie R. R., Pittsburg, Pa.* R. P. Forsberg. (13) Jan. 2.
Switching Yards of the Chicago Transfer & Clearing Co.* (13) Jan. 2.
Les Locomotives à l'Exposition de 1900: Locomotives Américaines. F. Barbier. (38) Dec.

Railroad, Street.

The Wannsee-Berlin Electric Railway.* (12) Dec. 6.
Shallow Underground Tramways. C. H. Wordingham, M. Inst. C. E. (26) Dec. 13.
Sprague Multiple Unit System, as Applied on the Boston Elevated Railway.* Frank J. Sprague. (26) Serial beginning Dec. 13, ending Dec. 27.
Street Railway Track Construction at Scranton, Pa.* (13) Dec. 26.
The Street Railway Company of Hamburg, Germany.* Heinrich Veilguth. (17) Jan. 4.
The Brighton Corporation Tramways.* (17) Jan. 4.
The Portsmouth Electric Tramways.* (17) Jan. 4.
Stock Rooms and Stockkeeping of the Metropolitan Street Railway Company, New York City.* (17) Jan. 4.
Le Matériel Roulant des Tramways à l'Exposition de 1900. Raymond Godfernaux. (38) Dec.

Sanitary.

The Sewerage of New Orleans.* W. T. Crotts. (1) Nov.
The Pollution of Streams by Manufactural Wastes, and Methods of Prevention. H. W. Clark. (28) Dec.
Refuse Destruction.* J. A. Priestley. (47) Dec. 7.
Sewage Disposal at Wauwatosa, Wis.* (14) Dec. 14.
The Melbourne and Metropolitan Sewerage System.* (14) Dec. 21.
Ventilation of an Office Building in Hartford.* (14) Dec. 21.
The Aramingo Drainage System, Philadelphia. Geo. E. Datesman. (14) Dec. 28.
Plumbing in the Tombs Prison, New York.* (14) Jan. 4.
Ventilateur "Sirocco" Système Davidson.* A. Soult. (36) Dec. 10.

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* Illustrated.

Structural.

The Coefficient of Expansion of Concrete.* Wm. D. Pence. (4) Dec.
The Identification of Wood.* Herbert Stone. (29) Dec. 6.
Some Interesting Features of Recent Chimney Construction.* (13) Dec. 19.
Tests of Fireproof Partitions by the New York Building Department.* (13) Dec. 26.
The Weehawken Elevator.* (14) Dec. 28.
Practical Application of Reinforced Concrete. Jacques Boyer. (9) Jan.
A Steel Frame Foundry Building.* (14) Jan. 4.
Les Planchers en Béton Armé de Métal Déployé: Système Golding.* (36) Nov. 25.
Des Applications du Cement Armé. G. Liebeaux. (38) Dec.

Water Supply.

Protection of Water Pipe from Electrolysis. E. B. Ellicott. (4) Dec.
The Bacteriological Analysis of Water and Its Interpretation. Charles-Edward Amory Winslow. (28) Dec.
The Work of Sanitary Inspection of the Metropolitan Water-Works. William W. Locke. (28) Dec.
Experiences in Reducing Water Ram Caused by Direct-Acting Pumping Engines. George E. Winslow. (28) Dec.
Water Supplies of Vermont. Charles P. Moat. (28) Dec.
Fall of the Fairhaven Water Tower.* R. C. P. Coggeshall. (28) Dec.
Clearing and Enlarging the Spot Pond Storage Reservoir, Metropolitan Water Supply.* Caleb Mills Saville, M. Am. Soc. C. E. (13) Dec. 12.
A "Tangential Impact" Water Wheel.* (13) Dec. 12.
The Needless Changes in the Jerome Park Reservoir Construction.* Alfred Craven, M. Am. Soc. C. E. (13) Dec. 19.
Water Power Development at Hannawa Falls. Wallace C. Johnson. (20) Dec. 26.
The Red Bridge Power Station of the Ludlow Manufacturing Company.* (14) Dec. 28.
Niagara Falls Power: The Organization of the Operating Department of the Niagara Falls Power Company.* Philip P. Barton. (10) Jan.
A Rock-Fill Dam with Steel Core across East Canyon Creek, Utah.* W. P. Hardesty. (13) Jan. 2.

Waterways.

The Lower Mississippi: Physical Characteristics, Methods of Improvement, Character and Volume of Traffic.* J. A. Ockerson. (1) Nov.
Present Condition of the Panama Canal. Gen. Henry L. Abbot. (9) Jan.

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* Illustrated.

ACCESSIONS TO THE LIBRARY.

DONATIONS.*

(From December 12th, 1901, to January 7th, 1902.)

THE CONSTRUCTION OF FOUNDRY PATTERNS.

An Elementary Manual for Engineering Students and Apprentices. By Herbert Aughtie, A. M. I. M. E. Cloth, 8½ x 6 ins., 8 + 166 + 2 pp., illus. The Scientific Publishing Company, Manchester, 1901. 5 shillings net.

In this work the author has endeavored to produce a textbook dealing with the principles of pattern making in such a way as to meet the requirements of engineering apprentices and students, though doubtless much of the information given will be found of value also to experienced workmen and foremen. In the treatment of the subject, brevity in the text has been aimed at, coupled with very full illustrated examples; and the examples have, as far as possible, been fully dimensioned, so that the bearing of the particular methods used may be more clearly apprehended. Foundry methods are frequently discussed, as the construction of a pattern very often cannot be undertaken until the method of moulding is decided upon. The first chapter contains a brief account of the method of moulding simple patterns in green sand, with such fundamental rules of pattern construction as apply practically to all cases. The following chapter discusses such complications of the mould as necessitate the use of loose parts in the pattern. Chapters III to VIII deal with the construction of circular patterns and the economy in the cost of patterns due to the use of skeleton patterns, loam patterns and loam moulds. Patterns of a more elaborate nature, such as those required for steam cylinders, toothed wheels, etc., are considered in the next four chapters, while the concluding chapter is devoted to a description of such machinery as is necessary or desirable in a pattern shop. There is an index of two pages.

HAND BOOK OF TIMBER PRESERVATION.

By Samuel M. Rowe, M. Am. Soc. C. E. and M. W. S. E. Souvenir Edition. Leather, 6 x 4 ins., 61 + 8 pp., illus. Chicago, Pettibone, Sawtell & Co., Printers, 1900. (Donated by the Author.)

The primary purpose of this little book, as stated in the introductory remarks, is to furnish and collate such information as to the practical workings of the preservation of timber as shall enable the operator to understand fully the philosophy and principles involved. and to serve as a handbook of information, both during the construction and operation of the works. The zinc-tannin, or Wellhouse, process is treated of at length, while the Burnett and creosote processes are noticed only incidentally.

STANDARDS FOR STRUCTURAL DETAILS.

American Bridge Company, Engineering Department. Cloth, 10 x 6¾ ins., 102 pp., tab., illus. 1901. (Donated by the American Bridge Company.)

In order to obtain uniformity, these standards have been prepared for use in the various engineering offices of the American Bridge Company to assist the engineers and draftsmen in making detailed and shop drawings. The present edition is a revision of former standards. The preface states that they have been revised from time to time in order to keep pace with the progress made in the art of designing, and that particular effort has been made to have them adapted to the latest improvements in tools used in bridge construction. The Contents are: Beams and Channels; Angles; Tees; Z-Bars; Rivets and Bolts; Pins and Nuts; Eyebars; Rods; Flooring; Miscellaneous; Tables; Sample Drawings; Corrugated Steel Windows and Doors; Rules for Making Shop-Drawings; Appendix.

COURS DE TRAVAUX MARITIMES

Professé à l'École Nationale des Ponts et Chaussées. Par Le Baron Quinette de Rochemont et M. Henry Desprez. Cloth, 11 x 7½ ins., 2 vols and atlas, illus. Paris, Ch. Béranger, 1900. 40 francs. (Donated by Baron Quinette de Rochemont.)

* Unless otherwise specified, books in this list have been donated to the Library by the Publisher.

The following gifts have also been received:

Adams, Edward A. 1 bound vol.
Am. Soc. Mech. Engrs. 1 bound vol.
Am. Water-Works Assoc. 1 pam.
Boston Pub. Lib. 1 vol.
Boston Transit Comm. 1 bound vol.
Buck, L. L., and Nichols, O. F. 1 bound vol.
Casper, C. M., Co. 1 bound vol.
Collingwood, Francis. 3 pam.
Colo. Agricultural Exper. Station. 1 pam.
Columbia Univ. 1 no.
Detroit Board of Water Commrs. 1 pam.
Duluth City Officers. 1 pam.
Endicott, Mordecai T. 1 pam.
Indian Midland Ry. Co. 1 pam.
Inst. of Civ. Engrs. of Ireland. 3 bound vol., 9 pam.
Lange, Gunardo. 1 pam.
McCann, T. H. 2 maps.
Mass. State Board of Health. 1 bound vol.
New England Cotton Mfrs. Assoc. 1 bound vol.
N. Y. State College of Forestry. 1 pam.
North, Edward P. 1 pam.
North of England Inst. Min. and Mech. Engrs. 1 pam.
Oesterreichischer Ingenieur- und Architekten-Verein. 28 vols., 71 nos.
Philosophical Soc. of Glasgow. 1 vol.
Schieren, Chas. A. 3 bound vol.
Thompson, Robt. A. 1 pam.
U. S. War Dept. 1 bound vol., 2 vol., 35 pam.
Vierendeel, A. 1 pam.
Wash. Bureau of Statistics, Agriculture and Immigration. 1 vol.

BY PURCHASE.

Les Automobiles Électriques. Par Gaston Sencier et A. Delasalle, avec une Préface de Charles Jeantaud. Paris, Ch. Dunod, 1901.

Recherches Expérimentales sur le Matériel de la Batellerie. Par F. B de Mas. Paris, Imprimerie Nationale, 1891–1897.

Technische Hülfsmittel zur Beförderung und Lagerung von Sammelkörpern (Massengütern). Von M. Buhle. I. Teil. Berlin, Julius Springer, 1901.

Geographische Abhandlungen. Herausgegeben von Prof. Dr. Albrecht Penck in Wien. 7 vols. in 14. Wien, Eduard Hölzel, 1886–1900.

Reminiscences of General Herman Haupt, giving Hitherto Unpublished Official Orders, Personal Narratives of Important Military Operations, and Interviews with President Lincoln, Secretary Stanton, General-in-Chief Halleck, and with Generals McDowell, McClellan, Meade, Hancock, Burnside, and Others in Command of the Armies in the Field, and his Impressions of These Men. Written by Himself, with Notes and a Personal Sketch by Frank Abial Flower. Milwaukee, Wright & Joys Co., 1901.

Sanitary Engineering. A Practical Treatise on the Collection, Removal and Final Disposal of Sewage and the Design and Construction of Works of Drainage and Sewerage, with a Special Chapter on the Disposal of House Refuse and Sewage Sludge, and Numerous Hydraulic Tables, Formulæ and Memoranda, including an Extensive Series of Tables of Velocity and Discharge of Pipes and Sewers Specially Computed by Ganguillet and Kutter's Formula. By Colonel E. C. S. Moore, R. E. New York, Longmans, Green & Co.; London, B. T. Batsford, 1898.

Zeitschrift des Vereines Deutscher Ingenieure (to complete set) 1 no.

SUMMARY OF ACCESSIONS.

December 12th, 1901, to January 7th, 1902.

Donations (including 3 duplicates and 72 numbers completing volumes of periodicals)	181
By Purchase (including 1 number completing volume of periodical)	7
Total	188

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
BEARDSLEY, JAMES WALLACE, Jun. Eng., U. S. Engrs., Old Custom House, Detroit, Mich		Dec. 4, 1901
DOUGLAS, EDWARD MOREHOUSE, Care, U. S. Geological Survey, Washington, D. C		Dec. 4, 1901
HOLGATE, HENRY, McKinnon Bldg., Toronto, Ont., Canada		Oct. 2, 1901
JOHNSON, LUCIEN SAMUEL, Jun. Eng., U. S. Inspector, U. S. Eng. Dept., Jamestown, R. I		Dec. 4, 1901
MACKENZIE, WILLIAM BROUARD, Chf. Eng. Intercolonial Ry. of Canada, Moncton, N. B., Canada	Jun. M.	June 7, 1882 April 3, 1901
MAITLAND, ALEXANDER, JR., Contr. Eng., American Bridge Co., 514 N. Y. Life Bldg., Kansas City, Mo		Nov. 6, 1901
TONE, SUMNER LA RUE, 5607 Howe St., Pittsburg, Pa		Dec. 4, 1901
TUCKER, LESTER WALDO, Asst. Eng., B. & M. R. R., Boston, Mass		Dec. 4, 1901
WALLACE, JOSEPH HARRISON, 908 Temple Court Bldg., New York City	Jun. Assoc. M. M.	Dec. 1, 1896 Dec. 1, 1897 Nov. 6, 1901

ASSOCIATE MEMBERS.

BELLOWS, OSCAR FRANCIS, U. S. Supt. of Constr., Fort Morgan, Ala	Dec. 4, 1901
DOWNMAN, JULIAN ROMNEY, Mgr., Teche Constr. Co., Jeanerette, La	Dec. 4, 1901
HILL, CURTIS, Sewer Dept., City Hall, St. Louis, Mo	Oct. 2, 1901
HUNTER, ROBERT EASTON, 644 St. Denis St., Montreal, Que., Canada	Nov. 6, 1901

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ADAMS, ARTHUR, 132 Oneida St., Utica, N. Y	Oct. 1, 1901
IVES, HOWARD CHAPIN, Worcester Polytechnic Institute, Worcester, Mass	Dec. 3, 1901
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	Date of Resignation.
Douglas, Henry Thompson	Dec. 31, 1901
Greenough, Malcolm Scollay	Dec. 31, 1901
Kelsey, Clifford Stephen	Dec. 31, 1901
Marshall, William Lewis	Dec. 31, 1901

DEATHS.

Crabb, Thomas........ Elected Junior April 4th, 1899; died Dec. 21st, 1901

Reece, Benjamin........Elected Member March 2d, 1881; died Dec. 17th. 1901

Stixrud, Martinius . . Elected Member April 3d, 1889, died Dec. 28th, 1901

Vol. XXVIII. JANUARY, 1902. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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Vol. XXVIII. JANUARY, 1902. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE BOHIO DAM.

By George S. Morison, Past-President, Am. Soc. C. E.

To be Presented March 5th, 1902.*

All engineers who have examined the route of the Panama Canal agree that the neighborhood of Bohio is the only available location for the dam by which the summit level must be maintained. On the other hand, there have been wide differences of opinion as to how this dam should be constructed, and how high it could safely be built. While it would be an exaggeration to say that the conditions met here are unprecedented, they call for engineering skill and judgment of the highest order. A dam built to meet requirements which have been imposed in other localities would be enormously expensive. The real skill of an engineer is shown in designing the least expensive safe structure adapted to the particular case in hand, even though it may not comply with requirements commonly demanded.

The formation of the Isthmus is generally volcanic, with the irregularities of surface, rocks, and elevations usually found in volcanic countries. The width of the Chagres Valley at any fixed elevation is very variable, while rocky islands rise here and there above the level of the alluvial plain. The sides of the valley are generally rocky, although

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers with discussion in full will be published in *Transactions*.

much of this rock is of soft character; it has often weathered into a fertile soil, which was formerly covered by a tropical forest, and would quickly return to its pristine condition if the rude cultivation now practiced were abandoned. The bottom land or alluvial plain of the river is comparatively narrow, and is formed of the sediment from a country of much the same character as that which bounds it. As the rocks are of very diverse character the alluvial soil is also variable. It is generally a silt or a compact mixture of sand and clay practically impervious to water, but in some places coarse sand and gravel are found. There are various bars and other obstructions in the river, some of which are rock in position, and others bowlders, gravel or sand.

At Bohio the high banks of the valley are near together, and rock is found quite near the surface on both sides of the river. The river is less than 200 ft. wide at ordinary stages, and a superficial examination would lead one to believe that rock would be found at very moderate depths completely across the valley. The first impression made is that this is an ideal site for a dam, and that a masonry structure could be built at moderate expense. Borings, however, reveal the unwelcome fact that the alluvial deposit has simply filled up an old, deep geological valley, the bottom of which, at places, is 140 ft. below tide level, and that the lower portion of this valley is filled with sand and gravel permeable to water. The course of the geological valley does not everywhere agree with the present bed of the Chagres River, but it lies within the hills which bound the larger valley. Permeable sand and gravel are found in the lowest part of the geological channel, overlaid by a heavy and tight blanket of finer alluvial deposit. There are strong probabilities that this permeable material connects with the river either above or below, or both, the evidence of this being that when a pipe is driven into this material the water in the pipe stands at the same level as that in the river. It is practically established, however, that there is no connection with the river for a considerable distance, probably at least ½ mile, above the dam site. Fig. 1 is a general map of this locality. The immediate location, on a larger scale, is shown in Fig. 2, and several cross-sections of the valley, determined by borings, are shown in Fig. 3.

About 2 miles above the dam site, a local tributary, the Gigante, enters the Chagres from the west. A low summit separates the Gigante

from the Chagres 2 miles below the dam site. The natural summit here is 67 ft. above tide water at the lowest part of the gap. Good rock foundation is found at this place, and it is in every respect an excellent location for a spillway. The floods of the Chagres must either pass through the present course of the Chagres by Bohio, or must pass over the gap at the head of the Gigante. To force them through the Gigante gap requires the construction of a dam, at or near Bohio, at least as high as the gap. Until this is done all the work at the dam site will be subject to interruptions and dangers from floods in the Chagres. There are no special difficulties attending the construction of the Gigante Spillway.

The Gigante Spillway is an ideal arrangement. When the Bohio Dam is completed and the spillway built, the entire discharge of the river will be through the Gigante gap, and the dam will be almost 3 miles away from what will then be the Chagres. This gap, however, is a comparatively late discovery. All the earlier French plans were based on spillways on each side of the Bohio Dam, and not far from it, discharging into diversion channels on each side of and parallel with the canal. The published plans of the New French Company show that its engineers have failed to realize the great advantages of the Gigante location; they provide only for the discharge of a portion of the river by this route, the remainder being taken through a spillway very near the dam. The Gigante Spillway is, however, a superb solution of the problem of the control of the Chagres, the whole work being done by a fixed weir with no complication of gates or sluices. A weir 2 000 ft. long can be built here, which will pass a maximum flood of any probable duration, with a surface not more than 5 ft. above the crest of the weir, and a maximum flood of indefinite duration, such as has never been known, with a surface barely 7 ft. above. The discharge of the river below can be kept at a safe distance from the canal, and made to pass over a low, marshy country of little value.

The final result of the completion of the works will be that the Chagres will flow through the Gigante gap, where it will pass over a masonry dam founded on rock. Above this dam will be a lake, about 40 sq. miles in area, not unlike many other artificial reservoirs which have been created on rivers. The present valley will be closed by an artificial barrier, this barrier being located about 2 miles from the

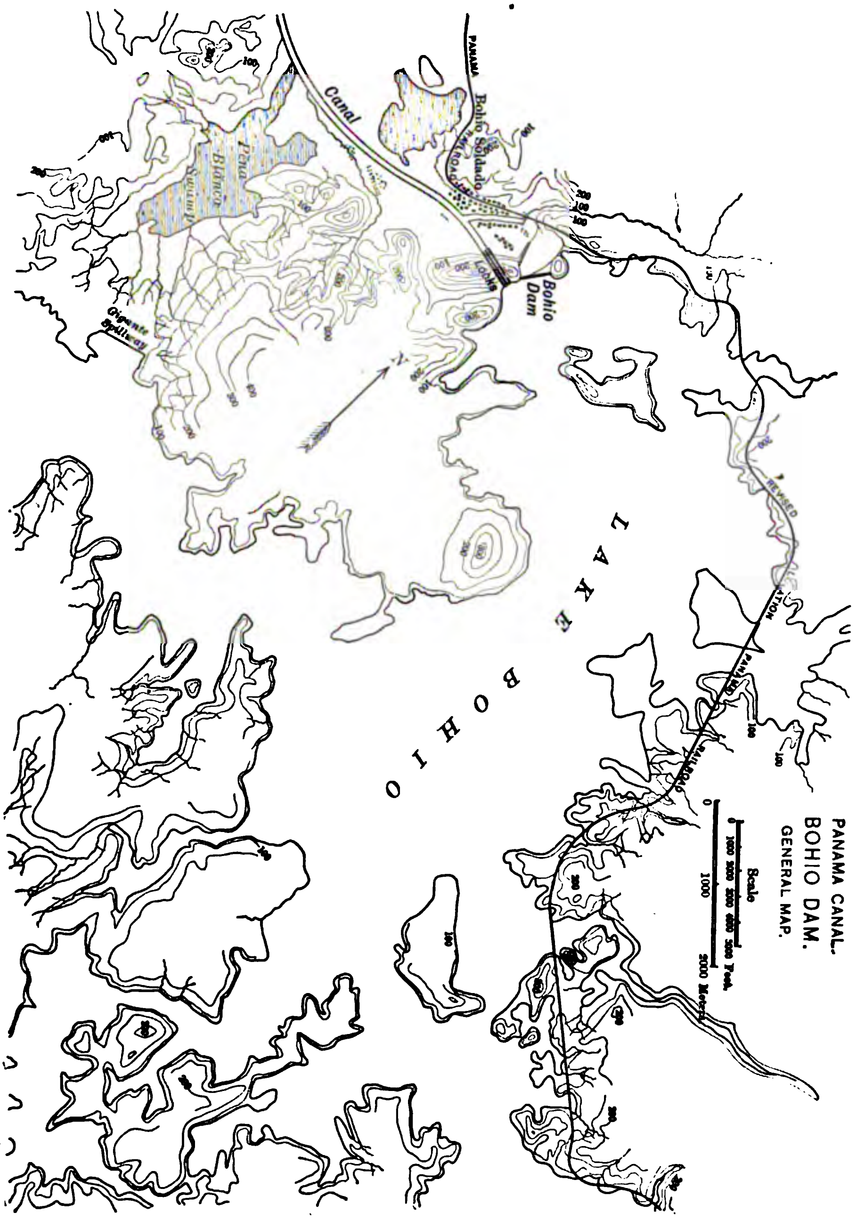

PANAMA CANAL.
BOHIO DAM.
GENERAL MAP.
Scale
LAKE BOHIO
Bohio Dam
Bohio Soldado
Canal
Pena Blanca Swamp
Gigante Spillway
PANAMA RAILROAD

FIG. 1.

during construction, a large amount of heavy rip-rap was to be placed on the down-stream face, this being designed principally to prevent the destruction of the work in case a flood should pass over the dam before it was completed. The only feature in which this dam can be said to differ materially from many other earth dams is the concrete facing on the up-stream slope, and this must be regarded as of doubtful expediency. A rigid surface of this character could not be expected to adapt itself to the irregularities of settlement, which are always likely to occur in heavy masses of earthwork; and cavities might form, of which there would be little danger if the surface covering were a loose one. This dam, like other earth dams, would not be safe against an overflow, but it would be tight in itself, and the only loss of water would be that which would percolate through the permeable material in the valley below the bottom of the dam. The importance of this seepage will be taken up later.

The Technical Commission, to whom the entire scheme of the New Panama Company was submitted for approval, thought it wise to limit the head of water against this dam to about 66 ft., or 20 m. There seems to have been no reason for this particular limit, except the general judgment, of the engineers forming the Commission, that it was not wise to expose an earth dam to a greater pressure of water.

To facilitate the construction of this dam, it was proposed to build a temporary dam of piles, timber and loose rock about 2 000 ft. above the permanent dam, and, during the construction of the permanent dam, to deflect the passage of the Chagres through the excavation made for the locks, which are but a short distance away. Should an extreme flood occur, exceeding the capacity of this channel through the locks, the work at the dam site would be flooded, and the heavy rip-rap outside the proper limits of the dam on the down-stream face was expected to save the works in case of such overflow. After the dam itself reached an elevation of 14 m. (46 ft.), it was calculated that there would be no further danger of overflow, and this special protection was not to be carried above this level. The construction of the dam could not really begin until the excavation of the locks had been completed, and the work on the locks must, in a great measure, be suspended while the dam is building. It seems to be important that these two works should be made as far as possible independent, which would be accomplished by building a temporary dam of such size that

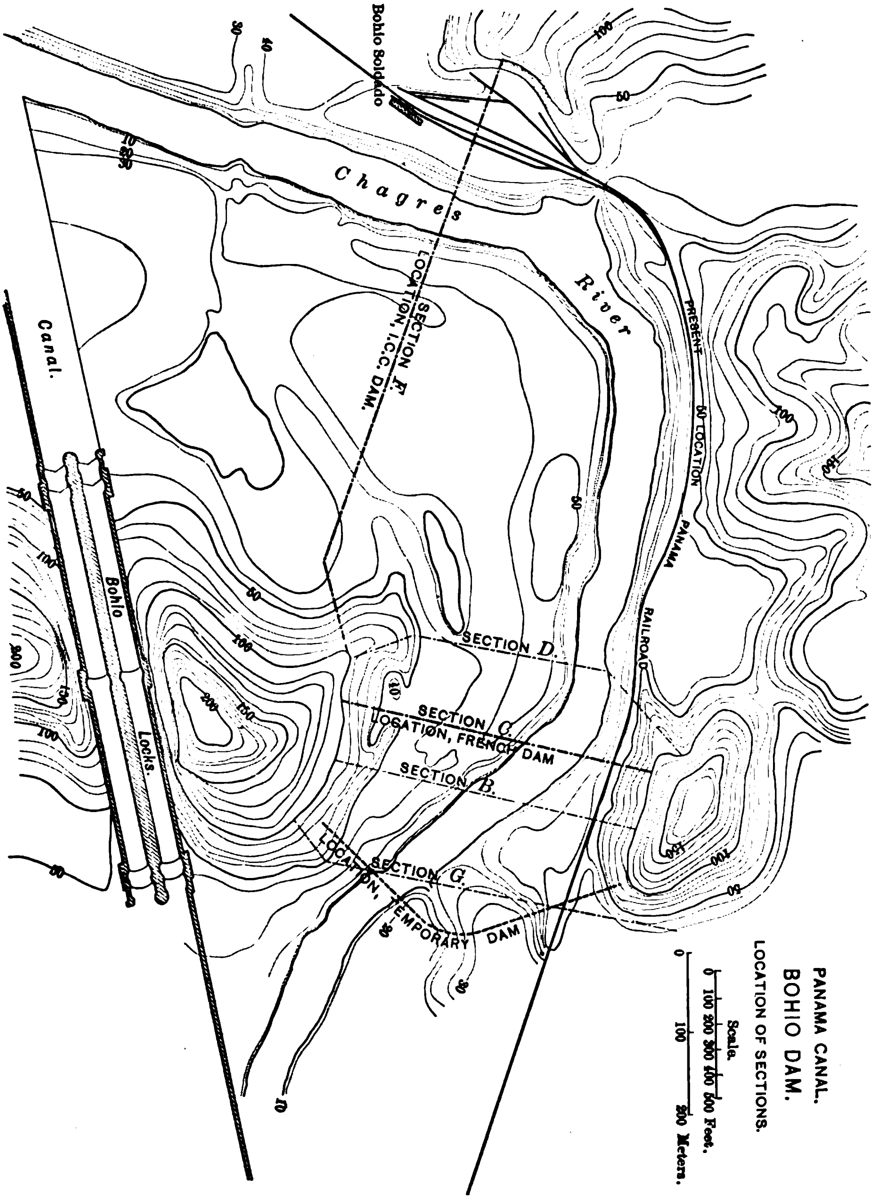

PANAMA CANAL.
BOHIO DAM.
LOCATION OF SECTIONS.
Scale.
0 100 200 300 400 500 Feet.
0 100 200 Meters.
Bohio Soldado
Chagres
River
Canal.
Bohio
Locks.
SECTION F.
LOCATION, I.C.C. DAM.
SECTION D.
SECTION C.
LOCATION, FRENCH DAM
SECTION B.
SECTION G.
LOCATION, TEMPORARY DAM
PRESENT
50 LOCATION
PANAMA
RAILROAD

FIG. 2.

the diversion would be through the Gigante gap, instead of through the excavation for the locks.

The detailed quantities involved in the construction of this dam, according to the French estimate, and the estimated cost are as given in Table No. 1.

TABLE No. 1.

Earth excavation, above tide level......	400 000	cu. m.	= 523 200	cu. yds.	at	$0.45	$235 440
" " below " "	62 250	"	= 81 423	"	"	1.00	81 423
Rock excavation........................	20 800	"	= 27 206	"	"	1.15	31 287
Earth placed in dam....................	326 100	"	= 426 539	"	"	0.60	255 923
Concrete and masonry laid in mortar..	29 650	"	= 38 782	"	"	8.00	310 256
Revetment of loose rock................	18 900	"	= 22 604	sq. yds.	"	2.00	45 208
Loose rock on down-stream face.......	139 800	"	= 182 858	cu. yds.	"	0.50	91 429
Timber in sheet-piling, etc............	3 260	"	= 1 385	M. B. M.	"	60.00	83 100
Total..							$1 134 066

The prices in Table No. 1 are those used in the Isthmian Canal Commission's Report, so far as they are applicable, and they are subject to such modifications as the judgment of engineers may think right. This estimate includes no temporary work. This dam is only 75 ft. high above tide water, the other designs being 100 ft. high. If, for purposes of comparison, the estimate be increased in proportion to the squares of these heights, the cost of the higher dam, on the French plan, would be $2 016 030, or, in round numbers, $2 000 000.

The Isthmian Canal Commission's Plan.—The plan adopted by the Isthmian Canal Commission was designed to resist a normal head of water of 90 ft., or about 25 ft. more than the limit arbitrarily adopted for the French dam. The design is based on the theory that the dam must not merely be tight in itself, but must absolutely close the valley, so that there will be no seepage either through it or below it. The plan selected consists of an earth dam 20 ft. wide on top, finishing 10 ft. above high water in the lake, with slopes of 3 horizontal to 1 vertical on both faces, broken by narrow horizontal benches, both surfaces being revetted with loose rock. This dam encloses a masonry core-wall, 8 ft. thick on top and 30 ft. wide at the base, which would be carried down to the underlying bed-rock. The location of this dam is shown in Fig. 2, and the elevation and cross-section in Fig. 5. The location was selected as one on which borings had indicated the maximum depth of rock to be the least, this depth being 129 ft. below tide water. The method of construction would consist in sinking

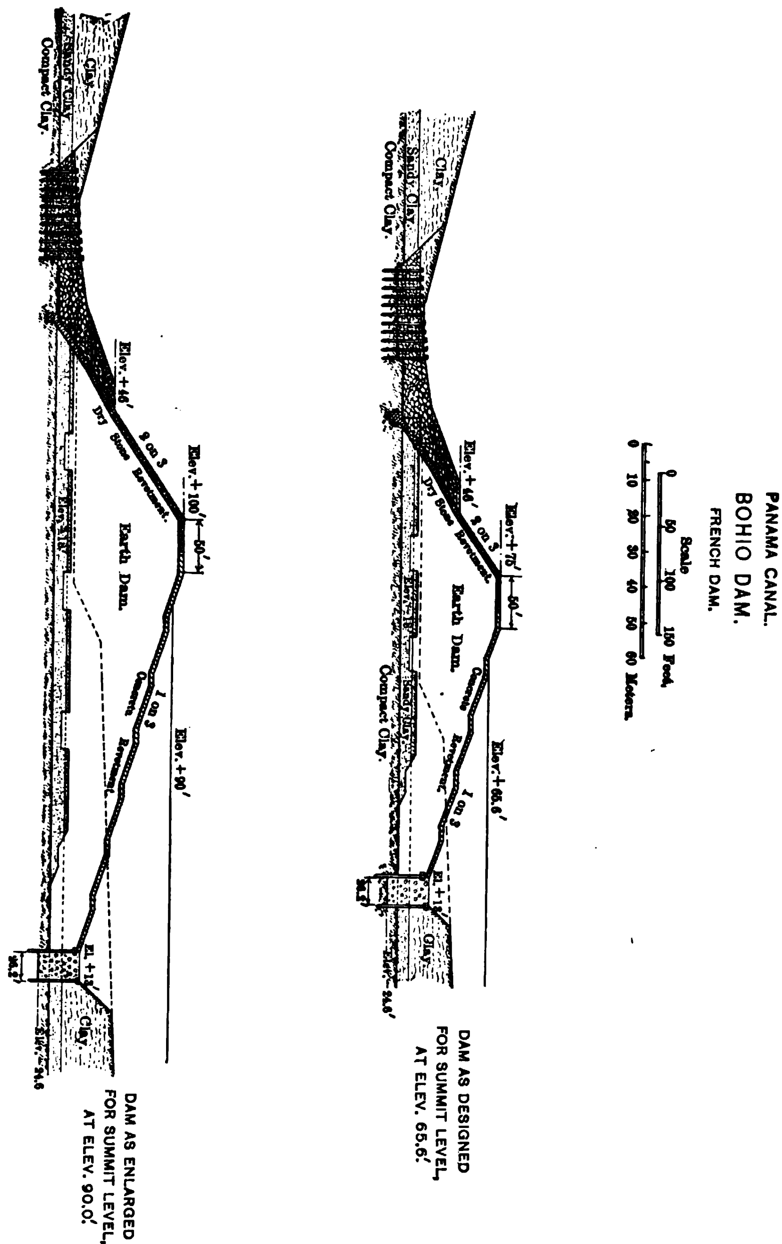

PANAMA CANAL.
BOHIO DAM.
FRENCH DAM.
Scale
0 50 100 150 Feet.
0 10 20 30 40 50 60 Meters.
DAM AS DESIGNED
FOR SUMMIT LEVEL,
AT ELEV. 65.6'
DAM AS ENLARGED
FOR SUMMIT LEVEL,
AT ELEV. 90.0'
Clay.
Sandy Clay.
Compact Clay.
Earth Dam.
Dry Stone Revetment.
Concrete Revetment.
2 on 3
1 on 3
Elev. +46'
Elev. +75'
Elev. +100'
Elev. +65.6'
Elev. +90'
50'

FIG. 4.

a series of pneumatic caissons, these caissons to be the foundation of a solid concrete wall, the two together constituting the core-wall. The design involves the extension of pneumatic work to unprecedented depths, and involves special details in making the joints between the caissons tight.

The location selected for this dam is below that chosen by the French engineers, and practically at right angles to the French dam; the length of dam, as well as the cross-section of the valley, on this line being double that on the French location. The desire to limit the depth of pneumatic work led to the selection of this line, but it is possible that additional borings might find a deeper hole here.

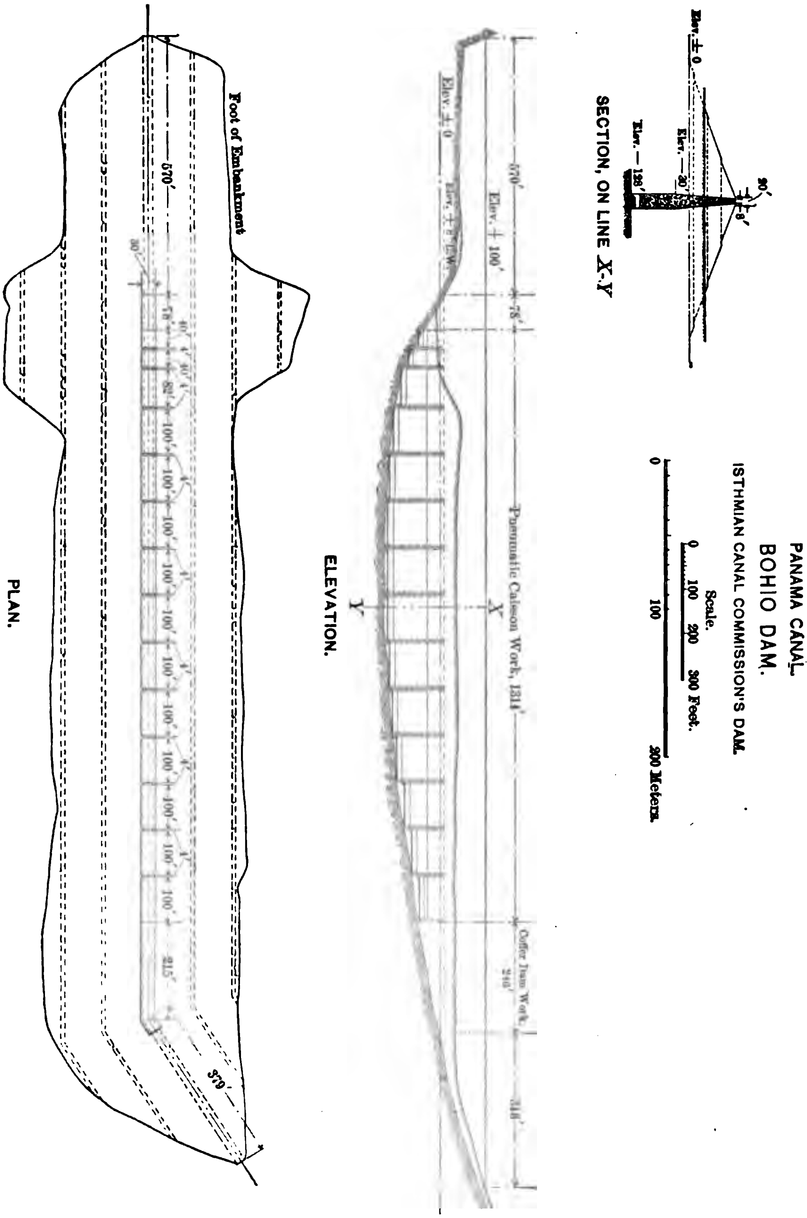
There can be little doubt that a dam of this character could be built. It involves novel and untried features. Few engineers, even among those who feel that they could construct it, would be ready to say in advance how the work would be done. The difficulties, taken in connection with the climate and other surroundings, are enormous.

The estimated cost of this dam, taken from the detailed estimates of the Commission, is as given in Table No. 2.

TABLE No. 2.

Earth excavation above tide level	255 500	cu. yds.	at	$0.45	$114 975
Excavation below tide level	7 260	"	"	1.00	7 260
Rock excavation	5 730	"	"	1.15	6 590
Pneumatic work	108 410	"	"	21.50	2 330 815
Concrete	286 950	"	"	8.00	2 295 600
Earth placed in dam	1 500 000	"	"	0.60	900 000
Revetment on both sides	107 200	sq. yds.	"	2.00	214 400
Total					$5 869 640

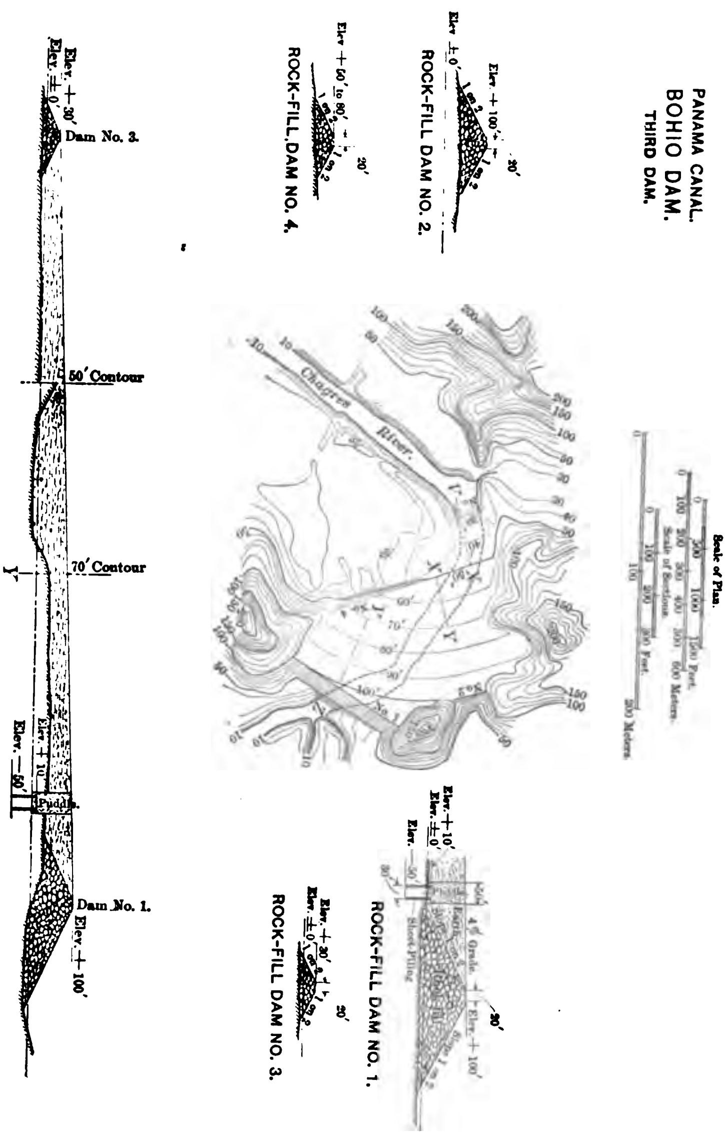
The cost of this dam could be very much diminished by adopting the French location, with its reduced cross-section of valley, and sinking the deeper caissons by dredging through wells, as has been done on many deep bridge foundations, instead of using the pneumatic process. With this method there would be less certainty of a water-tight joint between the caissons and the rock, and between the adjacent caissons. The effect of the core-wall would be to limit the deep-water seepage rather than to close it entirely. In the judgment of the writer, the small difference between the two would not justify the greatly increased cost which the Commission's plan involves.


PANAMA CANAL.
BOHIO DAM.
ISTHMIAN CANAL COMMISSION'S DAM.
Scale.
0 100 200 300 Feet.
0 100 200 Meters.
SECTION, ON LINE X-Y
Elev. ± 0
Elev. — 30'
Elev. — 128'
ELEVATION.
Elev. ± 0
Elev. + 100'
Pneumatic Caisson Work, 1314'
Coffer Dam Work
Foot of Embankment
570'
379'
215'

PLAN.
FIG. 5.

The Third Plan.—The dam proposed by the writer is designed to sustain a head of 90 ft., or the same as that proposed by the Isthmian Canal Commission. It is based on diverting the Chagres through the Gigante gap during the construction of the dam, and contemplates the use of a dam of very large dimensions, using material which would otherwise be wasted, this material consisting partly of rock from the excavation for the Bohio Locks and partly of earth excavated from the line of the canal. The dam is designed to be tight in itself, but no attempt is to be made to prevent seepage through the permeable material below the bottom of the dam, except so far as this can be done by sheet piling. In this respect this dam agrees with the French plan. Furthermore, after a careful study of the various other locations which the extensive borings made by the Commission indicated might be better, the French location has been chosen as the one best fitted for a structure of this kind, but the dimensions of the two dams differ so greatly that only a portion of the section of this dam really occupies the French location.

The general arrangement of this dam consists of two rock-fill dams, one located about 200 ft. above and the other about 2 000 ft. below the French location. The upper dam would finish at Elevation 100, or 10 ft. above the level of the water impounded in the lake. The lower dam would finish at Elevation 30, or 70 ft. below the upper dam. The space between the two rock-fill dams would be filled with impermeable material, the two dams being retaining-walls which would hold this earth in position; the surface of this earth filling would have a grade of 4% sloping from the lake, which is much flatter than any slope of saturation. The upper dam would abut against a hill separated from the high country beyond it by a gap lower than the level of the lake, and a small rock-fill dam of the same description would be required in this gap. Another small rock-fill dam would be required on the down-stream side of the earth filling, at a place where the natural surface of the ground is lower than the proposed filling. All four of these dams would be of the same class of construction, although but one of them would be of any considerable size. For convenience, the upper dam is designated as Dam No. 1, the dam across the gap as Dam No. 2, the low dam across the river as Dam No. 3, and the side dam as Dam No. 4. The location of these dams is shown in Fig. 3, and a cross-section is shown in Fig. 6.



SECTION VXYZ.

FIG. 6.

The four rock-fill dams would all be made on the same plan; they would finish 20 ft. wide on top, with slopes of 2 horizontal to 1 vertical on both sides, and they would be made entirely of loose rock taken from the excavation for the Bohio Locks, which would be deposited here in the same way in which rock fills are ordinarily made. The total amount of excavation for the Bohio Locks is estimated at 1 084 664 cu. yds. The estimated volume of the four dams is 555 000 cu. yds. Allowing for voids in the dams, the excavation for the locks would furnish three times the amount of rock needed for dam construction.

On the line of the French location, and immediately below Dam No. 1, it is proposed to drive two lines of sheet-piles, 30 ft. apart, from one rock bank to the other; these piles to be 60 ft. long, driven 50 ft. below tide water and terminating 10 ft. above tide water; the object being to exclude the flow of water within these limits. They will not check any flow of water at a greater depth, but 50 ft. is considered as great a depth as it is safe to estimate on driving. The upper 10 ft. of these piles would be buried in a puddle wall, 50 ft. thick, which would be laid up as the earth filling proceeds, and would be carefully rolled and compacted as it is made.

The entire space bounded by the rock-fill dams and the hills which they connect would be filled with clay and other earth excavated from the canal, which would be deposited here instead of being wasted elsewhere; it would generally be brought in by trains from the canal below Bohio, but if thought best it could be brought from the great Culebra Cut, the northern spoil bank from which is only 17 miles away. The surface of this earth filling should be planted with some tropical grass, and carefully maintained until all danger of settlement or of surface washing is over, when it might be allowed to grow up into a forest.

The estimated cost of this dam is as given in Table No. 3.

TABLE No. 3.

Rock-fill dam No. 1..........	450 000	cu. yds.	at $0.50	$225 000
" " " 2..........	27 200	"	" 0.50	13 600
" " " 3..........	32 000	"	" 0.50	16 000
" " " 4..........	46 300	"	" 0 50	23 150
Puddle wall.................	150 000	"	" 0.60	90 000
Earth filling.................	2 895 000	"	" 0.25	723 750
Timber in sheet-piling.......	812	M. B. M.	" 60.00	48 720
Total..................			....	$1 140 220

The prices given for rock-fill work (50 cents per cubic yard), and for the earth filling (25 cents per cubic yard), are considered very liberal, as they cover only the additional cost of depositing material here which would otherwise be wasted elsewhere. This is especially true with regard to the rock, the locks being very near the dam. The price for earth is equal to $2 per mile for train service between the Culebra spoil bank and the dam. The same price was used for loose rock deposited on the down-stream face of the French dam. All other prices in all three estimates are the same as those used by the Isthmian Canal Commission in its report.

Temporary Dam.—None of the foregoing estimates includes any provision for a temporary dam by which the waters of the Chagres would be diverted through some other route during the construction of the permanent dam. The French plans contemplated a dam of very small dimensions, and the temporary discharge of the Chagres through the excavation made for the Bohio Locks. Even with the French plan it would be desirable to send the river through the Gigante gap. To do this, a dam must be built which will raise the level of the river above Elevation 65; in other words, it must perform the same duties which the permanent French dam was intended to perform, but the dam may be of more perishable character and a greater seepage may be permitted. In northern climates this dam could be built largely of timber, but the life of timber on the Isthmus is so short that its use must be dispensed with, even for provisional work.

If the Commission's plan is adopted, the best location for the temporary dam would probably be about 600 ft. below the location of the French dam, where the valley is very narrow. If either of the other dams is built, a location must be found further up stream. The position of the temporary dam herein described is shown in Fig. 3.

The location selected crosses the river at right angles about 250 ft. above the foot of the up-stream slope of rock-fill Dam No. 1, and, making an angle near the east bank, connects with the high ground beyond. Rock is found here at reasonable depth for the whole width of the river, though not of the valley. The Chagres is about 150 ft. wide at low water, and the total length of the dam at Elevation 75 is 1 400 ft. The portion of the dam across the river proper must be built

in water; the portion beyond the limits of the river can be built on dry land. The general features of a dam designed for this location are shown in Fig. 7. It consists of two parts, a metal and masonry dam extending across the river, and an earth dam across the bottom land. The foundation consists of a series of separate piers, everywhere founded on rock, the greatest depth being 62 ft. below mean tide and 70 ft. below the water in the Chagres. These piers are connected by arches at the top while the spaces between them are closed by masonry shutters. It is quite probable that all these foundations could be put in with open coffer-dams, but pneumatic work has been estimated on for the four deeper piers. The steel superstructure would consist of a series of bents, spaced 30 ft. apart, and carrying a dam of steel plates. The earth dam is an embankment, 20 ft. wide on top, with side slopes of 2 horizontal to 1 vertical, a loose stone revetment on the up-stream side and a line of sheet-piling driven along the center. The earthwork and masonry could be built at the same time. The openings between the four piers are sufficient to pass the whole discharge of the Chagres during the low-water season. The steel dam could be erected in 90 days; this would be done during the dry season, while the river is passing through the sluices. After its completion, the sluices would be closed by shutters, and the water allowed to rise on the dam. The estimated quantities and cost of this dam are as given in Table No. 4.

TABLE No. 4.

Pneumatic excavation....	22 180 cu. yds.,	at	$12.00	$266 160	
Open excavation below tide level....................	1 900 "	"	1.15	2 185	
Concrete masonry	42 740 "	"	8.00	341 920	
Steel.....................	1 610 000 lbs.,	"	0.075	120 750	
Metal dam complete....................................					$731 015
Earth embankment........	200 000 cu. yds.	"	0.60	$120 000	
Sheet-piling..............	244 M.B.M.	"	60.00	14 640	
Revetment................	9 900 sq. yds.	"	2.00	19 800	
Earth dam complete....................................					154 440
Total.....................					$885 455

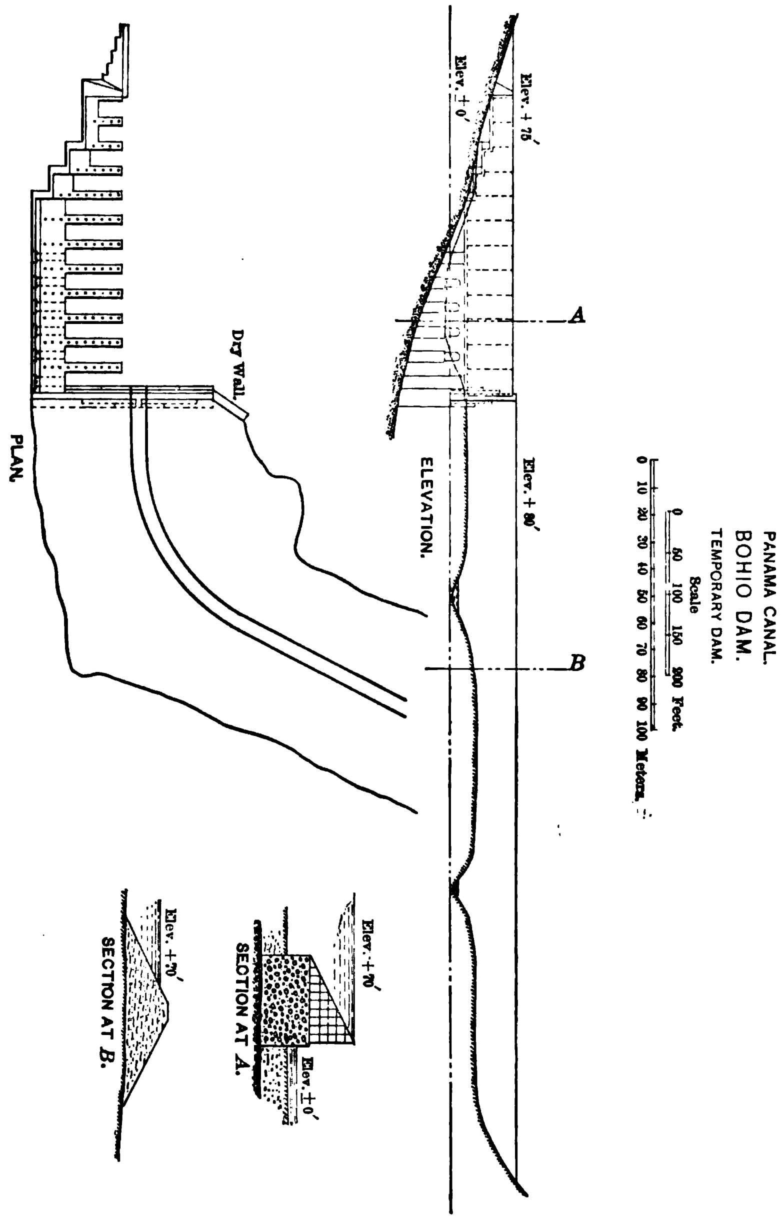

PANAMA CANAL.
BOHIO DAM.
TEMPORARY DAM.
Scale
0 50 100 150 200 Feet.
0 10 20 30 40 50 60 70 80 90 100 Meters.
Elev. + 75'
Elev. ± 0'
A
B
Elev. + 80'
ELEVATION.
Dry Wall.
PLAN.
Elev. + 70'
Elev. ± 0'
SECTION AT A.
Elev. + 70'
SECTION AT B.

FIG. 7.

This seems a very large price for a temporary dam, and the foregoing description must be regarded more as a study than as a definite plan. It is quite probable that a better and more economical structure could be devised. Furthermore, if rock-fill Dam No. 1 could be completed to a safe height above any possible overflow in a single low-water season, the necessity for the temporary dam might be avoided. This rock-fill dam complete is estimated to contain 450 000 cu. yds., and a similar dam finishing at Elevation 75 would contain 300 000 cu. yds. To complete the latter in a single dry season would require an average of 2 000 cu. yds. per day, which would be active work, but not impossible. The site of the main portion of the dam below this rock-fill dam would not thereby be rendered dry, but it would be in a safe condition for work.

Complete Comparison.—If this estimate be added to the previous estimates of the cost of the three respective designs, calling the French estimate $2 000 000 (as all permanent dams are supposed to finish at Elevation 100), the total cost of the three would be as given in Table No. 5.

TABLE No. 5.

	Permanent dam.	Both dams.	With 20% added.
French plan	$2 000 000	$2 885 455	$3 462 546
Commission's plan	5 869 640	6 755 095	8 106 114
Third plan	1 140 220	2 025 675	2 430 810

It is probable that the cost of the temporary dam to be used in connection with the Commission's plan could be somewhat reduced, while there is a possibility that it could be avoided with the third plan, but, in a general way, it may be said that, in the light of our present knowledge, the respective estimates should be, approximately, $3 500 000, $8 000 000, and $2 500 000.

This, however, does not tell the full story. On the American Isthmus the difficulties attending the use of skilled labor are very great. The amount of skilled labor required on the French dam is comparatively small; the Commission's plan requires a large amount; in the third plan the use of skilled labor is practically limited to the construction of the temporary steel dam and its masonry foundation. The third plan really means the construction of an elevated plateau of very large dimensions, the surface area of the earth filling between

the rock-fill dams being 57 acres. These dimensions may almost be called stupendous. The only dam known of similar dimensions is the so-called North Dike of the Wachusett Reservoir, at Clinton, Mass., the general features of which very closely resemble those of the dam which the writer proposes for Bohio. The criticism which has been made on the third plan is that it permits seepage through the permeable sand and gravel in the lower part of the geological valley.

Seepage.—In considering the effect of seepage, the absolute amount is not so important as the relative amount. The total requirements of the canal have been estimated as 1 000 cu. ft. per second, of which less than 500 cu. ft. would be used for lockage and 200 cu. ft. are required for evaporation, leaving more than 300 cu. ft. for leakage, seepage and other undetermined losses. This quantity (1 000 cu. ft. per second) is equivalent to 28.3 cu. m. per second, which seems very small. On the other hand, it is equivalent to 650 000 000 galls. per day, which exceeds the water supply ever furnished to any city in the world; it is, in fact, an enormous quantity. Except for four months in the year, the discharge of the Chagres very greatly exceeds this amount, and it is possible by additional storage to provide a supply at all times of about 2 500 cu. ft. per second. A loss by seepage, which might prove fatal under a dam sustaining a reservoir for the supply of a fairly large city, would be comparatively harmless in the present case.

Either dam proposed would itself be practically impervious. The puddle wall in the last design may be considered entirely so, and the filling generally would consist of water-tight earth, loose sand and gravel being excluded. The rock-fill dams at the two ends are loose, and would pass water, but the entire structure, including the rock-fill dams, would be founded on water-tight earth, which forms a thick blanket over the sand and gravel below. The distance between the up-stream slope of Dam No. 1 and the down-stream slope of Dam No. 3 is 2 400 ft. in a straight line; the actual distance which water must travel to pass between these points is at least ½ mile. To this should be added the distance from the dam to the place above, where the geological channel may connect with the present river; this distance is not accurately known, but it can hardly be less than ½ mile; in calculating the seepage, however, it has been entirely

neglected, and the distance which water must travel through a bed of sand and gravel has been assumed to be 2 500 ft.

On the line of the puddle wall, the cross-section of the valley, above the rock and below the line of sheet-piling, is 23 000 sq. ft. At a place 300 ft. farther down the valley the borings showed a cross-section of 10 000 sq. ft. of permeable material. Borings at other points indicate that this is probably a fair average of the amount of permeable material through the entire distance. For purposes of calculation this amount has been doubled, and 20 000 sq. ft. assumed as the average cross-section. The question to determine, then, is the amount of water which will filter through a bed of sand 2 500 ft. long, with a cross-section of 20 000 sq. ft.

Seepage has generally been considered a matter which must be guessed at, rather than calculated, and the opinions of engineers have differed greatly as to what it would probably be. The introduction of filtering plants, however, has led to experiments on the action of different sands in filter beds, and these experiments, while limited in dimensions, have given comparatively definite results, which seem applicable here. In fact, these experiments bear at least as close relations to the case in hand as the hydraulic experiments by which weir formulas have been determined bear to a dam across a great river. So far as there are any indications, it would appear to be probable that these filter-bed formulas, when applied to sand beds of very great thickness, will give results too high, rather than too low. The formula deduced from experiments* made by Allen Hazen, M. Am. Soc. C. E., is

$$V = c\, d^2 \, \frac{h}{l} \, \frac{t\,\text{Fahr.} + 10}{60}$$

in which V is the speed, in meters per day, at which the water will issue from the entire cross-section of sand; c is a constant, varying from 450 to 1 200, according to the cleanness of the sand; d is the effective diameter of the sand, in millimeters; h is the head; l is the distance which the water must pass through the sand, and t Fahr. the temperature of the water, in degrees Fahrenheit. The effective diameter is the diameter of a sphere the volume of which is greater than that of the grains which form one-tenth of the weight, and less than that of the grains which form nine-tenths of the weight of the whole mass.

* Report of Massachusetts State Board of Health, 1892, page 553.

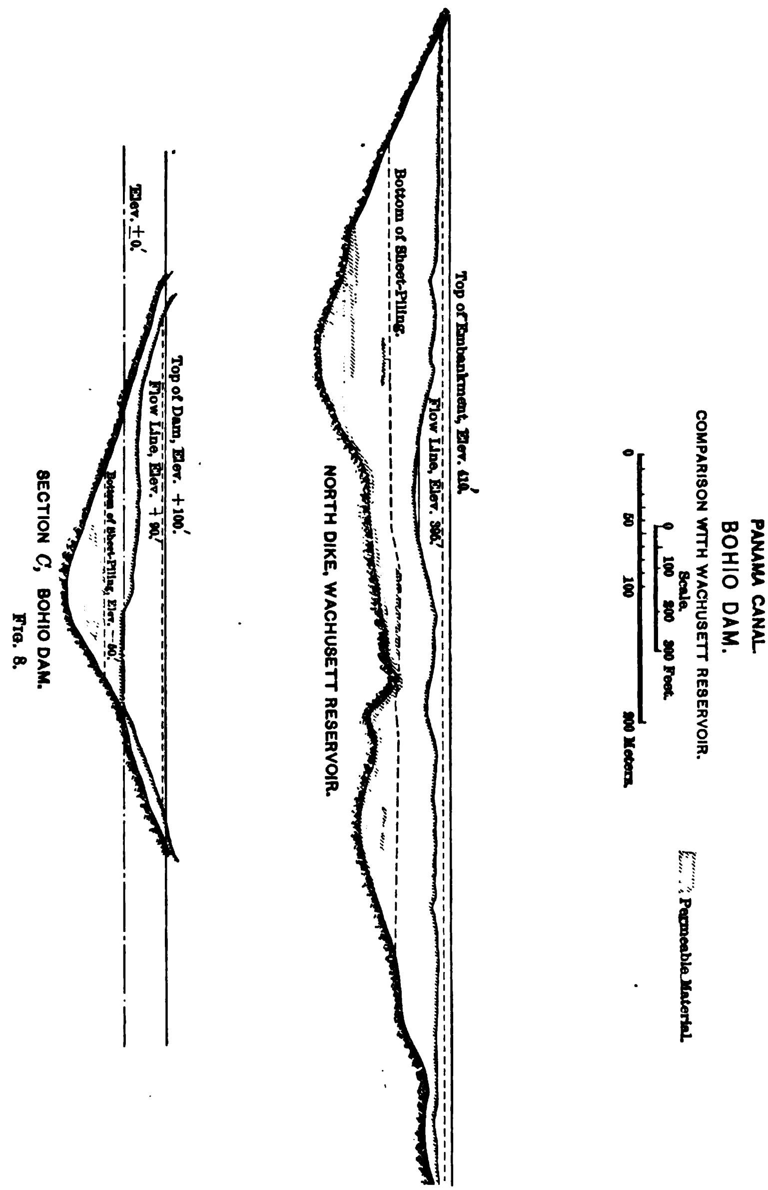

PANAMA CANAL.
BOHIO DAM.
COMPARISON WITH WACHUSETT RESERVOIR.
Scale.
0 100 200 300 Feet.
0 50 100
Permeable Material.
Top of Embankment, Elev. 416'
Flow Line, Elev. 386'
Bottom of Sheet-Piling.
NORTH DIKE, WACHUSETT RESERVOIR.
Top of Dam, Elev. +100'
Flow Line, Elev. +90'
Bottom of Sheet-Piling, Elev. −80'
Elev. ±0'
SECTION C, BOHIO DAM.

Fig. 8.

Putting $c = 1\,000$; $h = 90$; $l = 2\,500$, and t Fahr. $= 90$, the formula becomes

$$V = d^2 \frac{1\,000 \times 90 \times 90}{2\,500 \times 60} = 54\,d^2.$$

If V_s represents the speed, in feet per second, we have

$$V_s = 0.000039\ V = 0.002\,d^2.$$

The value of d is determined by an inspection of the sand and gravel. Eight different specimens of sand and gravel taken from bore holes were analyzed by Mr. Allen Hazen, and the effective diameters reported as follows: 1.3, 2, 0.9, 0.22, 1.6, 0.38, 0.49, 0.57. The average of these is 0.93, but, if they are averaged by their squares, the average is 1.11. As these were selected as specially coarse specimens, they undoubtedly give a much higher value than that of the average material in which the flow in the pipes was lost. Furthermore, they are all washed specimens brought up from the bottom, and do not fairly represent the actual condition of the material in position. If the value of d be assumed as 1 mm., which is only 10% less than the average by squares, the value is probably at least double that which actually exists. Putting $d = 1$, we have

$$V_s = 0.002.$$

Applying this value of V_s to the assumed cross-section of permeable material (20 000), the total seepage would be 40 cu. ft. per second, an insignificant amount compared with the total water consumption of the canal. It is only about one-fifth that required for evaporation. Furthermore, it is probable that this amount is grossly over-estimated. If the value of d be taken at 0.5, the value of c at 500, and the value of l at 5 000, this seepage will be reduced to 2½ cu. ft. per second. Even if, at the beginning, the conditions agree with this assumption, the sediment, in the flood water of a few years, will change the value of the several constants to those last named. As these conclusions may be considered remarkable, it is thought worth the while to call attention again to the large figures with which we are dealing. The quantity ½ cu. ft. per second is about 1 600 000 galls. per day, an adequate water supply for a manufacturing town of 40 000 people, or for the whole population now living on the Isthmus.

The speed at which 40 cu. ft. would issue from a surface equal to the cross-section of the permeable material is 0.002 ft. per second. The rate at which it travels through the voids in the sand, however, is very much greater, but would not exceed 0.008 ft. per second, or ½ in.

per minute, being about the speed of the minute hand of a fair-sized clock. While a large aggregate of water can pass through a large section of sand at this low speed, the speed is not enough to move any material except on an open exposed face of comparatively steep slope. As the outlet, if any exists, is considerably below tide level, such disturbance is impossible.

Wachusett Reservoir.—Reference has already been made to the North Dike of the Wachusett Reservoir, near Clinton, Mass., where the situation bears a striking resemblance to that at Bohio. In both instances a large reservoir or lake is created by a dam across a river, and in both instances this dam must be supplemented by an embankment or another dam across a gap lower than the level of the lake. At the Wachusett Reservoir, the masonry dam closes the present channel of the river, and the dike or embankment is across a low gap which marks the site of the geological valley. On the Isthmus, the masonry dam is across the low gap, and becomes the spillway, while the embankment is across the present river, but not across the river as it will be when the works are completed. At the Wachusett Reservoir, the geological valley was filled with drift, and the deflection to the site of the masonry spillway was made by glacial action. On the Isthmus, the deflection from the geological valley to the site of the spillway must be made by artificial means, no glaciers ever having reached that tropical country. When the work is done, the two conditions will be substantially the same.

The head of water on the two sides of the dams will not differ in the two locations enough to affect the percolation materially, the water in the Wachusett Reservoir being more than 100 ft. above the water in the river below, although the actual height of the embankment on its immediate location is somewhat less. The depth of the geological valley is much greater at Clinton than at Bohio, as is also the cross-section of the permeable material. For the purpose of comparison, the two cross-sections have been drawn on the same scale in Fig. 8.

The dams differ principally in the character of the material used for their construction. In place of rock-fill dams, gravel embankments are being used at Clinton; and, in place of material taken from the canal, the strippings of the lake, or surface soil with a considerable amount of vegetable mould, have been used for filling between these embankments. The same principles govern the percolation and seepage in both cases.

Vol. XXVIII. JANUARY, 1902. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THERMO-ELECTRIC MEASUREMENT OF STRESS.

By C. A. P. Turner, M. Am. Soc. C. E.

To be Presented March 19th, 1902.

In undertaking the labor of preparing a paper on this subject the writer was influenced by the hope that a full description of the methods used, combined with an exhibition of the results obtained under somewhat unfavorable circumstances, together with a few remarks regarding the errors involved and the probable accuracy attainable under more favorable conditions, might lead to further investigation along this line, supplying reliable data as to the fiber stress in columns, the extent of stress induced in members and details of structures by the impact and vibration under rolling loads, together with some insight as to the magnitude of secondary stress, resulting from the character of the details used.

Further, as will be noted later in the paper, this method appears to throw some light on the limits at which molecular fatigue commences to appear, confirming Bauschinger's suggestion that in Wohler's experiments, in which bars broke nominally below the elastic limit of the material, there is reason for concluding that the loads were really greater than the true elastic limits of the bars.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers with discussion in full will be published in *Transactions*.

Methods of Measurement.—In the measurement of stress by thermo-electric means, two radically different methods may be used.

A.—By relative measurement of the temperature change in the bar when the load is applied or removed. This method is applicable only while the load is being applied or removed, and cannot be used at any time thereafter, as the thermal change in the bar is gradually dissipated by radiation.

B.—By measurements indicating the extent of the temporary change in the thermo-electric intensity of the bar, due to the stress applied. This change subsists as long as the constraining force is kept applied, and hence the method is applicable to the measurement of either live or dead-load stresses.

In the work done thus far by the writer, measurements by the first method have been reduced to a basis approaching scientific accuracy, while sufficient work only has been done by the second method to indicate its practicability with suitable apparatus, and give reason for thinking that the same amount of time spent in improving the method of operation will place it on nearly an equal footing with direct thermal measurement.

Returning now to the first method: The general law upon which the thermal measurement of stress depends may be stated as follows: Any substance which expands upon being heated absorbs heat (*i. e.*, grows cooler) upon being stretched, and *vice versa.*

Sir William Thomson (*Lord* Kelvin) has developed* the mathematical theory of the thermo-elastic properties of matter, and has demonstrated the following formula as applicable to the phenomena in question:

$$H = \frac{t\,p\,e}{J\,S\,W};$$

where H = thermal increase, in degrees Centigrade;

t = temperature, Centigrade, from absolute zero;

J = the mechanical equivalent of the thermal unit;

p = pressure applied, in pounds, positive if compression and negative if tension;

e = the longitudinal expansion per degree Centigrade;

S = the specific heat;

and W = the weight, in pounds per foot of length of bar.

* *Quarterly Mathematical Journal*, April, 1855; reprinted in the *Philosophical Magazine*, 1878.

This change in temperature, as would be inferred from the undulatory theory of heat, takes place instantaneously, with the application of the pressure, or load, p, and is subject to the usual laws of radiation. Since the temperature change is very small, Newton's Law of Cooling may be taken to apply exactly, namely: The amount of heat gained or lost by a body in a given time is proportional to the difference in temperature between the body and the surrounding medium. Hence, if two loads, of different magnitudes, are gradually applied in equal periods of time, the temperature changes in the bar for the respective loads will be strictly in proportion to the loads, notwithstanding the radiation going on while the loads are being applied.

The formula, $H = \frac{t\,p\,e}{J\,S\,W}$, is rigidly exact for any solid only for an infinitesimal increment in p; but, with steel, the variation within the elastic limits would be extremely small, and may be taken as exactly proportional to the pressure or load applied, and, as we are interested only in relative measurements, no error is involved.

As H depends on t, the temperature of the bar at the time the load is applied, this temperature should be noted, if readings taken at different temperatures are to be compared. Thus, if the value of absolute zero be taken at -276.7° Cent., and one set of measurements is taken at 23.3° Cent., and another at 24.3° Cent., the latter, for the same loads, should be $\frac{1}{3}$ of 1% greater, if no error has been made in the work. As t would probably not vary greatly, this percentage per degree Centigrade is sufficiently accurate for most purposes.

The magnitude of the temperature change, H, may be best illustrated by a few figures. Take the temperature of a bar at 19.3° Cent., p at 1 lb., and the area of the bar at 1 sq. in., and we have, for mild steel, $H = \frac{(276.7 + 19.3) \times 1 \times 0.00001142}{1400 \times 0.11 \times 3.34} = 0.00000657^\circ$ Cent., the temperature change for a change in stress of 1 lb. per square inch.

To one not familiar with thermo-electric work, this temperature change per pound per square inch would seem to be much too small to admit of measurement, but this is by no means the case, if, in connection with the thermo-pile, there is used a galvanometer as sensitive as a Thomson astatic. The range through which we may measure, however, will be correspondingly small, as may be best illustrated by the result of the following test, by Mr. McIntyre and the writer, using a fairly sensitive adjustment of an Elliott Brothers' instrument.

On application of a load of about 30 lbs. per square inch on the bar, a deflection (scale reading) of more than 60 cm. was noted (a deflection which is nearly the maximum which may be read). This is at the rate of 2 cm. per pound per square inch; and, as 0.3 mm. is a very appreciable deflection, we would readily note a change in temperature in the bar of one ten-millionth part of 1° Cent., caused by the application of a load of about ¼ oz. per square inch, and this is by no means the limit.

For practical purposes, however, we would of course desire to take the measurements through a range of several thousand pounds per square inch, and an adjustment which would give a deflection of 2 cm. per 1 000 lbs. would be suitable. Now, with such an adjustment we would endeavor to read to 0.1 mm., which, with this adjustment, would correspond to about 5 lbs. per square inch, giving a temperature change of a little more than three hundred thousandths of 1° Cent. This being the probable error of reading with such an adjustment, the percentage of error in the reading would decrease, the greater the deflection, being $\pm$ 0.5% for 1 000 lbs., and $\pm$ 0.1% for 5 000 lbs., per square inch, etc.

Apparatus.—The necessary apparatus will now be described in detail. It consists of a thermo-pile, or junction, attached to and insulated from the bar, in circuit with a suitable galvanometer, provided with the usual reading scale and telescope for reading the deflections. In the experiments, given the load was applied to the bar by an Olsen testing machine, and weighed off as carefully as possible. A wire index was attached to the end of the scale beam, and a scale was fastened to the standard, in order to enable the operator to weigh, as accurately as possible, the load applied.

In the writer's early work in this line the galvanometer used was a Thomson astatic, manufactured by Elliott Brothers. While this is an excellent instrument, it is more sensitive than necessary, and has the serious disadvantage of being affected by the slightest external magnetic or electrical disturbance. Hence, in the later work, a D'Arsonval type of galvanometer was used, which, from the character of its construction, is practically uninfluenced by conditions which would render a Thomson useless.

The D'Arsonval type consists of a permanent horse-shoe magnet, between the poles of which is suspended by a bronze fiber a coil of

copper wire. The current passes down the fiber and through the coil, and the coil tends to place itself at right angles to the lines of force of the magnetic field. As the coil turns it is resisted by the torsion of the fiber.

Assuming the field to be constant, the torsional resistance of the fiber is, within the elastic limits, in proportion to the deflection angle, $\triangle$, while the lever arm of the deflecting force is cosine $\triangle$. Hence, the current strength is in proportion to the angle, $\triangle$, divided by the cosine $\triangle$, while the readings (the zero being at the center of the scale) are to each other as the tangents of twice the deflection angles.

Were the field strictly uniform, the mathematical corrections to the readings could be readily made and applied. The assumption, however, that we have a constant field may be far from exact, and should be investigated experimentally.

Using a standard cell, giving a constant current, we may, by the use of suitable resistance boxes, arrange to shunt but a small fraction of the current through the galvanometer, and, by varying the resistance, may vary the current passing through the main circuit; then, placing a standard ammeter in the main circuit, we can measure the current, and, by comparing the galvanometer deflections with the readings for current strength, we may determine the galvanometer corrections.

As we cannot read the ammeter with the same precision that we can read the galvanometer, it is better to use a large tangent galvanometer in place of an ammeter, where this type of instrument would not be disturbed by earth currents, caused, as was the case in the laboratory where the writer worked, by the proximity of electric street-railway lines, which prevented a more accurate investigation of the instruments used.

The temperature correction, in the comparison of measurements made at different temperatures, has been noted, but it should also be noted that any change in temperature changes the resistance of the copper wires in the circuit and coil, and a correction should be made for this, where the accuracy of the work would warrant such a refinement.

The most difficult correction to deal with satisfactorily is that of time or radiation, since the measurements depend on:

1. The temperature change in the bar, which is effected by radiation;

2. On the conduction of this temperature change to the end of the pile next to the bar, through the insulating material;

3. On the time required for the galvanometer to register the full amount of deflection.

In the experiments presented in this paper, the time recorded is that from the time of starting to apply the load until the reading was taken, and an attempt was made to determine the percentage of error involved for a given percentage of increase or decrease in the time noted for each application of the load. One of the difficulties of doing this accurately lies in the fact that the galvanometer reading is nearly stationary for a second or two at or close to the maximum, and it is difficult to determine the time exactly.

Where the time of application of the load is short, say, 25 to 35 or 40 seconds, a considerable difference in the observed time appeared to make little or no appreciable difference; while, where the application of the load was made at a much slower rate, say, 1 minute to 1 minute, 20 seconds, a variation of 10 or 12 seconds appeared to make a quite regular, though small, percentage of difference in the reading for a number of experimental determinations.

One feature of the apparatus, which was given much thought and attention, was the proper method of attaching the junction, and the method finally used was somewhat novel.

In the writer's early work, difficulty was experienced with the antimony-bismuth pile by its getting in contact with the bar, and short-circuiting, thus making the readings unreliable; then, if he tried to compare different readings, the distance or air space between the end of the pile and the bar might have varied, and the results could not be compared with a high degree of accuracy.

Again, air being a poor conductor of heat, the results were not altogether satisfactory from this standpoint. To obviate this the bar was given a coat of shellac, and the thermo-pile applied. By this means much better results were secured. It appeared, however, that a little difference in the thickness of the coating of shellac and in the time which it had been allowed to dry made some little difference in its conductivity, and an attempt was next made to make the junction with gum-arabic in place of shellac, using a very thin piece of paper coated on each side, moistened, and applied to the bar, and the thermo-pile pressed against the other side.

This not proving wholly satisfactory, rubber cement was used for the junction. It was found that this could be applied quickly, would dry in a few minutes, and, as it gave a thin uniform coating, measurements with different junctions could be compared with a fair degree of accuracy. The thermo-pile was held in place on the bar by elastic bands.

In addition to the cap over the outer end of the pile, to protect it from air currents, the head of the machine was wrapped with heavy asbestos board and carpeting, and, in order to keep note of any temperature change that might occur, a thermometer was inserted through the covering, and read at intervals, while a thermometer was placed outside in order to keep note of temperature changes in the room.

The laboratory where the experiments were performed, while admirably equipped for the purposes intended, presented few advantages for the work in hand except the convenience of the Olsen testing machine. The room itself was subject to air currents and considerable temperature changes, and the galvanometer, instead of having a specially prepared masonry base on which to stand, was set up on the plank floor. A further disadvantage of earth currents, due to electric street-railway traffic, has been referred to.

Fig. 1, Plate I, is a side view of the large testing machine used, with the covering of the head not yet applied. It shows a thermo-pile attached to each side of the bar. The wire index and scale, to assist in weighing accurately, may be seen at the right.

Fig. 2, Plate I, shows the machine in the background, with the head covered, and in the foreground the two galvanometers and the telescopes with scales for reading the deflections. The large galvanometer at the left is a Queen instrument, the field of which was found to be very nearly constant, the readings requiring but slight corrections. The instrument to the right is a small Knott galvanometer. The field magnet of this consists of three steel horse-shoe magnets a small distance apart, and, as would be expected, the field was not exactly constant, and further, the suspending fiber, being very short, was more easily over-strained, and was less reliable. Hence, the results with the small galvanometer are not nearly so reliable as those obtained with the Queen instrument, and its use, where two sets of readings were taken, was more as a check to determine whether

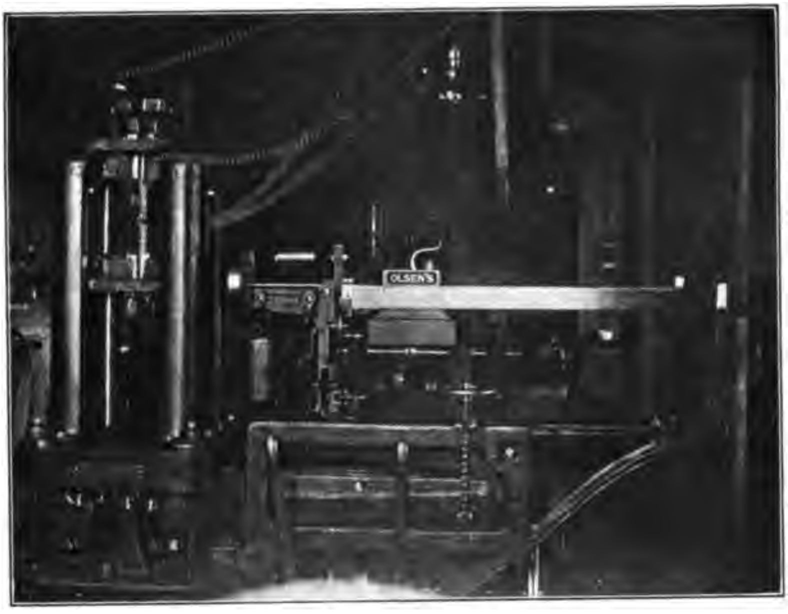


FIG. 1.—LARGE OLSEN TESTING MACHINE.

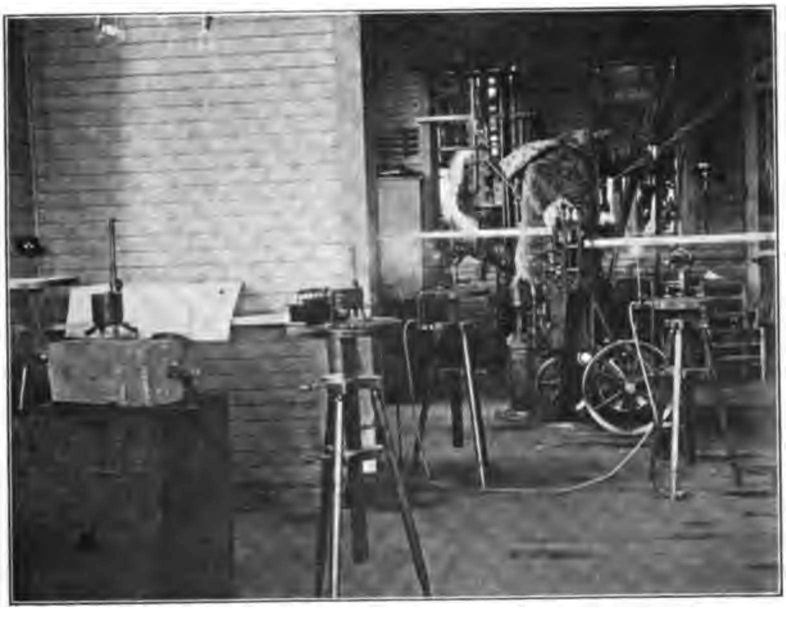


FIG. 2.—GALVANOMETERS, SCALES, ETC.

the bar was in bending or not. The importance of this can better be understood by bearing in mind the fact that the readings represent the mean fiber stress on the bar only in so far as the load is uniformly distributed over the section of the bar; thus, if the bar were slightly bent the tension would be considerably greater on one side than on the other, by the amount of bending in the bar, and this difference would be indicated by comparing the readings of the two galvanometers, and would be particularly noticeable as the bar straightened out under increased load. In other words, the galvanometer readings indicate the average fiber stress immediately under the area covered by the thermo-pile. Where the chucks are not exactly in line with the bar a certain amount of bending may result from this cause. Some of the bars were planed and some were rough, as is noted in the description.

Plate II shows the small Olsen testing machine.

For the benefit of any who may be interested in experimental work in this line, a statement of the cost of the necessary apparatus may be of interest, and the following figures are approximately correct:

Queen D'Arsonval galvanometer	$40.00
Telescope and scale	35.00
Stand	5.00
Antimony-bismuth thermo-pile, 36 couples, about	30.00
Wire	0.50
Rubber cement	0.25
Benzine	0.25
Total	$111.00

For work such as the writer has endeavored to do, duplicate apparatus would be found more desirable than the use of galvanometers and piles of different size and make. Thus, the large thermo-pile noted had 49 couples, the small thermo-pile had 25.

The experiments given cover only tensile stresses. The writer had made, previously, a number of experiments on short bars in compression, sufficient to determine the general character of the thermal-stress curve in compression, but, as compressive tests are far more difficult to make accurately than tensile tests, and the writer's time was limited, none was attempted for this paper.

Thermal Stress Curve.—The mathematical law of change in temperature with the application of compressive or tensile stress has been noted, and attention will now be called to the limits within which this law holds good.

In soft steel of good quality, ranging from 50 000 to 58 000 lbs. per square inch, ultimate strength, this limit appears to be from 18 000 to 23 000 lbs. per square inch. When the pull exceeds this limit the temperature change is no longer proportional to the pull or load applied. The curve deviates from a straight line, at first slowly, then more and more rapidly as the yield point is approached, when heat is rapidly generated.

For medium steel from 60 000 to 70 000 lbs. ultimate strength, this thermal limit of proportionality is considerably higher, from 23 000 to about 27 000 lbs. per square inch, and when the stress exceeds this limit the curve appears to deviate more rapidly from the straight line than is the case with the softer and tougher metal. When the yield point is reached, or approached closely, heat is generated more rapidly than is the case with the softer metal.

Under compression, the metal under stress grows slowly and regularly warmer, in proportion to the pressure applied, until approximately in the vicinity of these limits, when the temperature increase is at a considerably more rapid rate, and, as the yield point is approached, there is, as was the case in the tensile test, a rapid rise in temperature.

Fig. 1 shows typical thermal-stress curves in tension and compression.

Relation of the Thermal Limit of Proportionality to Fatigue.—Referring to Fig. 1, it will be noted that the thermal limit of proportionality is lower than what is usually considered the true, primitive elastic limit of the metal, and the question as to the reason naturally arises; and, further, what is going on within the metal and between the molecular groups that caused the deviation of the thermal curve from a straight line?

Evidently, were there any cause producing heat, it would offset the cooling effect of stretching the metal. Now, it is known that as the yield point is reached there is a very considerable amount of heat generated, accompanying the breaking down of the structure of the bar and the flow of the metal, and it may well be inquired whether this

TYPICAL THERMAL STRESS CURVES.

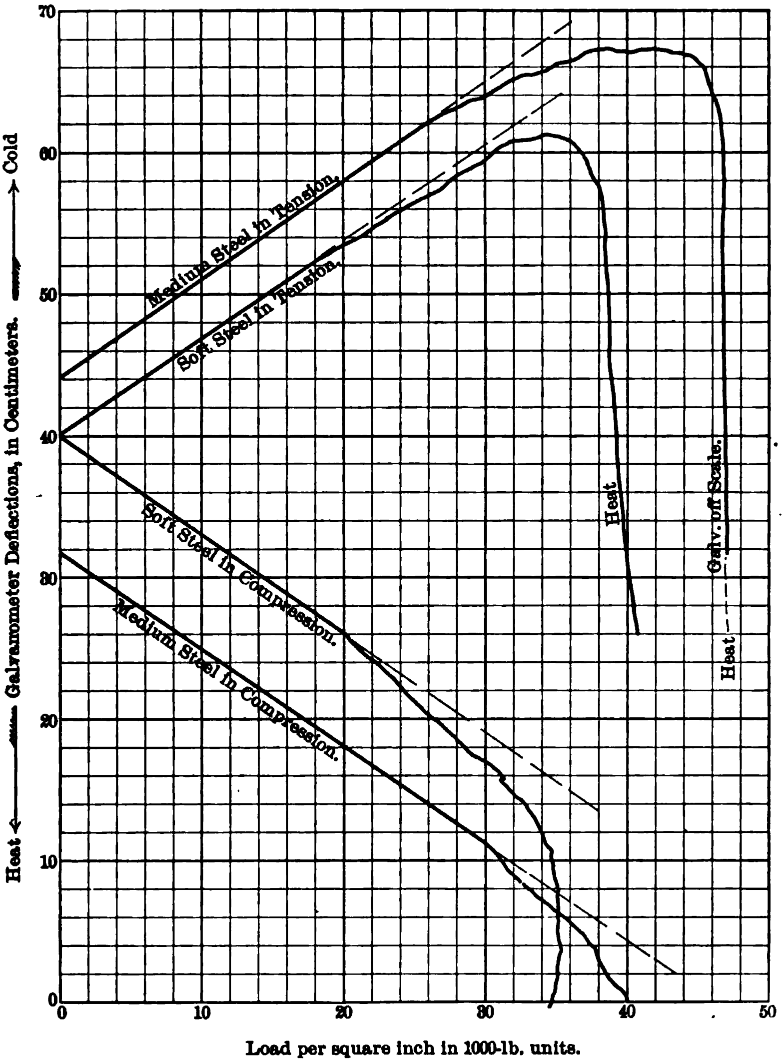


FIG. 1.

limit of thermal proportionality marks the incipient stage of this change in structure under stress. If this be the case, then this limit should agree closely with Wohler's range for unlimited repetition for alternating stresses, which appears to be the case.

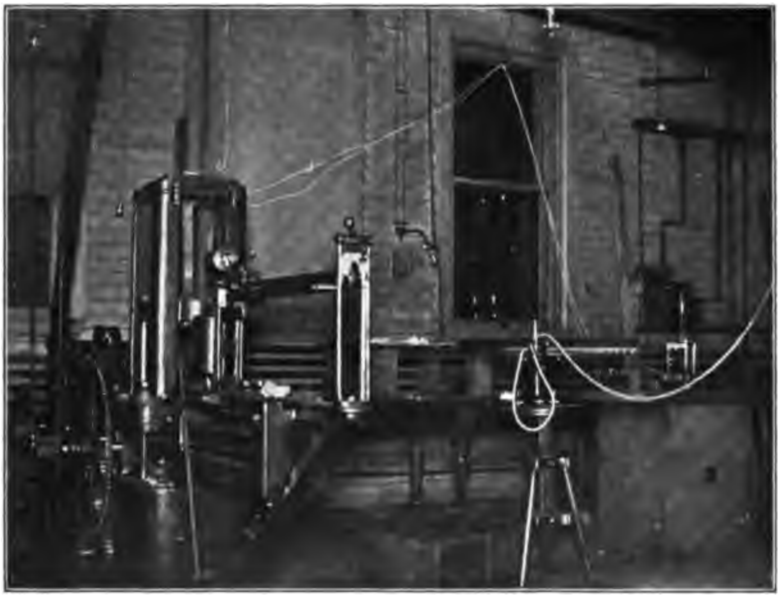
Further, if the deviation of the thermal curve from the straight line (indicating the heat generated by non-elastic, internal friction) be taken as a measure of the injurious effect of the range of stress above this limit, then it should be inferred that the harder metal would show, in proportion to its strength, inferior endurance as compared with the softer metal, under repetition of all stress of sufficient magnitude to induce fatigue, and the accuracy of the inference seems to be substantiated by the comparison of all the records of endurance tests on the two classes of metal.

If there is any such internal friction as has been assumed accompanying the strain of the metal beyond the thermal limit of proportionality, but within the apparent limit of the proportionality of shape, it must be conceived that there has been an expenditure of energy in overcoming the internal resistance of the breaking up of molecular groups, and friction incident thereto. Granting this, its cumulative effect would be in evidence in the increase of the period and the rate of subsidence of the elastic vibrations of the specimen. Thus, in Thomson's experiments, two similar and equal pieces of copper wire were put up, about April 26th, hanging with equal and similar lead weights, similarly fixed by soldering. No. 2 was more frequently vibrated than No. 1, but no comparison was made until May 15th; then No. 1 subsided from 20, initial range, to 10, in 97 vibrations, while No. 2 gave the same subsidence in 77 vibrations. During the greater part of May 16th and 17th, No. 2 was kept vibrating, and No. 1 quiescent, and experiments were made, with the following results:

No. 1	subsided	from 20,	initial	range, to 10,	in 99	vibrations	of 2.4	seconds.
No. 1	"	20,	"	" 10,	" 98	"	" 2.4	"
No. 1	"	20,	"	" 10,	" 98	"	" 2.4	"
No. 2	"	20,	"	" 10.	" 58	"	" 2.45	"
No. 2	"	20,	"	" 10,	" 60	"	" 2.45	"
No. 2	"	20,	"	" 10,	" 57	"	" 2.45	"
No. 2	"	20,	"	" 10,	" 60	"	" 2·45	"

This series of experiments, from which the foregoing has been quoted, indicates elastic fatigue for the considerable range of stress through which they were conducted, this range being, of course, within

PLATE II.
PAPERS, AM. SOC. C. E.
JANUARY, 1902.
TURNER ON THERMO-ELECTRIC
MEASUREMENT OF STRESS.



Small Olsen Testing Machine.

[illegible] ELASTICITY OF [illegible]

[illegible] limit of [illegible] of shape. Accordingly, it was sup- [illegible] for all [illegible] of shape [illegible] a similar and more [illegible] than [illegible] This limit is probably [illegible]

[illegible] in the [illegible] in all [illegible] of [illegible] in the [illegible] of [illegible] it might, [illegible] of [illegible] by [illegible] number of [illegible] the internal [illegible] of viscosity, [illegible] mechanism. [illegible] in the ab- [illegible]

[illegible]

the apparent limit of elasticity of shape. Accordingly, it was supposed that this elastic fatigue occurred for all stresses within the apparent limit of elasticity of shape until a similar and more extensive series of experiments, conducted by H. Tomlinson, showed that no such fatigue of elasticity is felt in steel, iron, or copper, providing the stress does not exceed a certain limit.* This limit is probably identical with the thermal limit of proportionality.

What, then, is the nature of fatigue? Johnson, in his "Materials of Construction," attempts to account for it by micro-flaws in the material. If their effect is the prime cause of ultimate fracture in all cases, we should look for their influence in the elastic fatigue of Thomson's experiments, but here we are met with an unavoidable difficulty in the condition that the elastic fatigue noted depended on the immediately previous molecular condition, whether of quiescence or recurring changes of shape.

Hence, if the speculation were to be continued further, it might, perhaps, well be along the lines of Maxwell's theory of viscosity, by supposing a temporary but progressive increase in the number of unstable configurations, or groups, of molecules under the internal friction noted, with a consequent temporary diminution of tenacity, resulting in the increased period of vibration noted, or in endurance tests in the ultimate development of temporary spots or planes of weakness, wherever these unstable groups chance to be a maximum, and final fracture corresponding to that of brittle material, in the absence of plastic drawing out.

Leaving this interesting field of speculation to others, the question which presents itself to us as engineers is this: If the fact can be established that, for the material we are using, there is a well-defined range of almost perfect elasticity, and beyond which there is a considerable, in fact, nearly equal, range of imperfect elasticity, before reaching the limits of apparent elasticity of shape, are we justified in considering the results of fatigue tests, under ranges of stress extending well into the latter range, as in anywise applicable to range of stress well within the former limit? In view of Bauschinger's work, the writer would hold that we are not.

Even though we discard making a special allowance for the effect of the range of stress of any kind, taking care of the impact and vibration

* *Philosophical Transactions*, Royal Society, 1886.

due to live load by a rational allowance, we have yet to consider somewhat the case of range of stress from tension to compression. Owing to the fact that the compression formulas give no direct data as regards the fiber stress in columns, we must needs allow an extra margin of safety to cover our ignorance in this respect, until we shall have developed our column formulas so that we know what the actual compressive fiber stress is, since Wohler's work shows beyond question the rapid injury resulting from range of stress from plus to minus when it exceeds well-defined limits.

Such an allowance, however, if our position be correct, should be based more rationally on the length of the column and the amount of the compressive stress involved, rather than upon the total of compression and tension, as is usually done.

Thus far in the consideration of fatigue tests it has been supposed that the stresses applied in the Wohler experiments were really or approximately those which he intended they should be—limited by the high degree of ingenuity displayed in the design of his testing apparatus to the approximate equivalent of a gradually applied load in the absence of shock.

Now, it is well known that the effect of a suddenly applied load in producing deflection is greater than that due to the same load at rest, and it may be demonstrated mathematically that were the load imposed with complete suddenness, or instantaneously and without shock, its effect is to produce a momentary deflection and strain twice that of the same load at rest.

Hence, Mr. Fidler argues that it is permissible to doubt whether the apparatus used by Herr Wohler did in fact succeed in limiting the internal stresses to the intended amount, without exceeding it, and whether the bars were not subjected to the action of dynamic stresses every time the load was applied, which was done about four times a minute. That this was the case to a certain extent can hardly be doubted, but what the limit of the dynamic effect was, is the question to be decided, if Wohler's results are to be interpreted on this basis.

A careful study of the Wohler machines would probably lead the majority of engineers to select at once that for repeated bending in opposite directions, as the one most likely to cause the maximum dynamic stresses, and perhaps the maximum estimate of this effect, in view of the slow speed of the machine, four revolutions per minute,

would be under 20 to 30% of the load on the cantilever end of the specimen.

Mr. Fidler's estimate for this, however, would be six to ten times that which we have made, by considering it possible that elastic vibrations induced might bring the internal stress up to the maximum effect of a suddenly applied load, which, in this case, would be three times the load, since the range of stress is twice the load.

The following is his table for the minimum breaking load, a, by the dynamic theory:

1. Steady load, no variation.................. $a = t$*.
2. Load varying from 0 to u.............. $a = u = \frac{t}{2}$.
3. " " " $-v$ to $+v$........... $a = v = \frac{t}{3}$

If we subject a bar to a suddenly applied load, the external work of the load is its weight times the deformation of the bar, which must be balanced by the internal work, which is the product of the mean stress times the elastic deformation: Hence, the deflection, or deformation, for the suddenly applied load, will be twice that caused by the same load at rest, since the mean internal stress is only half the maximum. If, however, this dynamic stress exceeds the yield point, part of the internal work will be performed in plastic deformation, resulting in raising the yield point, just as with a steadily applied load. Hence, in ductile material, a suddenly applied load greater than half the ultimate strength would have to be applied a number of times to produce rupture, and on this basis Mr. Fidler undertakes to account for the endurance of specimens in the Wohler experiments where the dynamic stresses would be (if figured on his proposed basis) considerably greater than the nominal strength of the material.

Now, the yield point in mild steel is approximately 60% of the ultimate strength, and, if we limit the range, plus and minus, of the alternate stresses in the Wohler machine to something less than one-third of the ultimate strength, the endurance of the piece seems practically indefinite, and the yield point has not been raised, as no plastic deformation occurs, although the dynamic stresses by Mr. Fidler's method of computation have exceeded the yield point by between 40 and 50 per cent. Since the conditions of application of the load

* t = ultimate strength, static test.

have been the same for the lower and higher intensities of stress, the same line of reasoning advanced to support the probable accuracy of the dynamic theory may be used with far better advantage to prove its improbability.

It has been argued that, in a short test piece under direct stress, the amplitude of the elastic vibrations under these dynamic stresses would be so small as to escape observation. This argument would have indeed some weight where the stresses are direct and the test piece short, but as similar fatigue occurs under bending, where the length of the specimen would insure so considerable an amplitude of vibration as to render their detection certain if these stresses were of anything like the magnitude supposed, the argument would seem to be invalid.

The final difficulty with this hypothesis will now be considered. If the dynamic effect of a load imposed instantaneously and without shock in producing deflection and stress may be readily proved mathematically to be momentarily twice that of the same load at rest, it by no means follows that we can do so if the time of application is extended through the interval of 15 seconds.

In fact, it would appear that this final absurdity has caused not a few engineers to discard the hypothesis, in framing their later specifications, and to make an allowance for the dynamic effect of loads on the more rational consideration of the length of span, or that portion of it which, when loaded, causes the maximum stress in the member, together with the character of the traffic, or the loading to which the structure is subjected.

Variations of the Thermal Stress Curve, under Varied Loading of the Specimen.

As will be observed by referring to the value of the temperature change for a change in stress of 1 lb. per square inch, the maximum cooling effect of stretching a bar up to nearly the yield point will be but little over one-fifth of 1° Cent., an amount too small to be appreciable by touching the bar with the hand. When the yield point is reached, however, the bar warms up very perceptibly, and this point in the curve may for convenience be termed the heat limit. This heat limit varies with the yield point, but the limit of proportionality of thermal change follows a different law. It may be readily lowered, but the writer has not apparently been successful in raising it above

its normal value. In fact, work thus far indicates, under treatment which is usually supposed to raise the limit of proportionality of shape, that, while the deviation of the thermal curve from a straight line for greater loads is much less marked, it commences at a much lower point.

The following tests are attached more as an example of the accuracy of thermal measurement of stress, rather than to demonstrate the foregoing general statements, for the reason that, while some of the tests appended were not made with sufficient care or under sufficiently favorable conditions to be of scientific value in determining the points referred to, they all indicate the value of the method as a means of measuring stress, and the best of them are probably within the limit of error involved in weighing off the load by the testing machine used. In fact, where the Queen galvanometer was used, the writer has no hesitation in stating his conviction that the galvanometer readings were far more accurate than it was possible to weigh the loads with the testing machine used. Especially in the tests where the Knott galvanometer was used, where the first scale reading differs materially from 30, the galvanometer correction is considerably in error for the larger deflections.

Again, the chucks of the large testing machine were such that the bar could not readily adjust itself to the line of pull, involving some little error in bending, which appears in some of the tests.

The heat from the lights used in the reading of the scale affected the pile on the side next to them to a small extent, which was noticeable in the change in the zero or first reading. Where a pile was used on each side of the bar it will be noticed that frequently one reading increased while the other decreased, showing bending, and if the thermo-piles had been of the same size these could have been correctly averaged, thus getting a true mean result.

In Experiment 5, a rough bar was slightly curved on one side, and straight on the other. The effect is quite marked, as may be noted by the readings.

Another error which is involved in making the corrections lies in the fact that the radiation correction was determined, while using rubber cement insulation for the junction, and was applied to the experiments made while using shellac insulation, for which it was probably somewhat too great.

In all cases the loads were applied by the hand-wheel of the testing machine, with as great regularity as possible. The percentage of error in weighing off the load was smaller for the smaller loads, for the reason that the weighing could not be done until after the galvanometer reading had been taken, as any vibration of the scale-beam would affect the reading.

It was noticed that the scale-beam would gradually sag after the application of a load of approximately 20 000 lbs., and the question arose as to whether this was due to squeezing the lubricant from between the teeth of the spur gears, and from between the thread and nut of the screws, or whether it indicated a certain amount of the actual stretch of the metal. If the latter, then the substitution of a bar of twice the size should change the position of this limit in weighing, but as the behavior of the scale-beam seemed to be the same, regardless of the size of the bar, it seemed evident that the first explanation was the correct one. The error involved would be this: The load weighed off would be slightly smaller than it should be, and hence the galvanometer deflection per 1 000 lbs. would be a trifle greater than it ought to be.

Experiment 1.

Evening, August 6th, 1901.

Bar No. 1. Size, 0.379 × 1.512 ins. = 0.573 ± 2 sq. ins. O. H. Steel; standard bridge specifications. Strip from web of 15-in. channel. Ultimate strength = 62 000 lbs. Elastic limit = 38 000 lbs.

Load.	Time.	First scale reading.	Second scale reading.	Deflection, in centimeters.	Corrections: Temperature.	Rad. corrected to 1' 30''.	Galvanometer.	Corrected deflection.	Deflection per 1 000 lbs.
	m. s.								
4 070........	1 42	40.97	49.65	8.68	0	+0.13	0	8.81	2.140
10 070........	1 30	40.36	61.88	21.52	......	....	−0.04	21.48	2.133
11 350........	1 25	40.12	64.38	24.26	......	−0.17	−0.05	24.04	2.118
13 000........	1 30	38.88	66.62	27.74	......	....	−0.08	27.66	2.128
15 075........	1 31	38.47	70.60	32.13	......	....	−0.11	32.02	2.124
17 000........	1 33	38.34	73.55	35.21	......	+0.17	−0.15	35.23	2.072
18 000........	1 39	38.17	75.25	37.08	......	+0.46	−0.17	37.37	2.076
20 000........	1 39	38.00	78.52	40.52	......	+0.50	−0.19	40.83	2.041

Queen D'Arsonval galvanometer, and thermo-pile of 49 couples, used. Shellac used for attachment. Distance of scale = 246 cm.

C. A. P. Turner, Observer. A. Zeleny, Operator.

Experiment 2.

Evening, August 8th, 1901.

Bar No. 2. Size, 0.378 × 1.488 ins. = 0.563 sq. in.

Load.	Time.	First scale reading.	Second scale reading.	Deflection, in centimeters.	Corrections: Resistance.	Temperature.	Rad. corrected to 1' 16".	Galvanometer.	Corrected deflection.	Deflection per 1 000 lbs.
	m. s.									
5 960....	1 15	66.09	79.50	13.41	+0.05	−0.18	−0.02	−0.01	13.30	2.248
8 000....	1 15	66.61	84.66	18.05	+0.07	−0.18	−0.08	−0.02	17.89	2.236
9 920....	1 22	66.70	88.89	22.11	....	0	+0.22	−0.04	22.29	2.237
11 040....	1 16	*66.70	91.33	24.63	....	0	0.00	−0.05	24.58	2.227
12 100....	1 20	54.28	80.84	26.56	....	0	+0.20	−0.06	26.70	2.207
13 120....	1 22	54.30	82.84	28.54	....	0	+0.29	−0.08	28.75	2.219
16 050....	1 19	54.30	89.00	34.70	....	....	+0.19	−0.14	34.75	2.165
18 040....	1 12	54.00	92.90	38.90	....	....	−0.26	−0.21	38.85	2.153
19 500....	1 16	54.30	95.40	41.10	....	....	0.00	−0.23	40.87	2.096

Remarks.—At the end of the second reading the temperature suddenly fell about 3° Cent., due to a shower. Doors open between readings.

Distance of scale = 246 cm. Queen galvanometer and large thermo-pile.

Shellac contact.

C. A. P. Turner, Observer. A. Zeleny, Operator.

Bar cut from web of the 15-in. channel of O. H. steel; manufacturers' standard specifications. Ultimate strength = 60 000 lbs. Elastic limit = 39 000 lbs.

Experiment 3.

P. M., August 9th, 1901.

Bar No. 2 (*Continued*).—Stretched to 21 000 lbs. the evening of August 8th. Large thermo-pile and Queen galvanometer.

Load.	Time.	First reading.	Second reading.	Deflection.	Corrections: Resistance.	Temperature.	Rad. corrected to 1' 18".	Galvanometer.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Rod.	Room.
	m. s.											
8 085...	1 16	34.50	55.48	20.98	......	......	−0.07	−0.03	20.88	2.582	22.7°	23.0°
10 070...	1 17	34.68	60.31	25.63	......	......	−0.04	−0.06	25.53	2 535	22.7°	23.0°
11 000...	1 18	34.80	62.80	28.00	......	......	0.00	−0.08	27.92	2.535	22.7°	23.0°
12 100...	1 17	34.89	65.67	30.78	......	......	−0.04	−0.10	30.64	2.532	22.7°	23.0°
14 170...	1 20	34.91	70.03	36.12	......	......	+0.24	−0.16	36.20	2.556	22.7°	23.0°
16 000...	1 15	34.91	76.20	41.29	......	......	−0.14	−0.23	40.92	2.557	22.7°	23.0°
18 050...	1 18	35.25	79.82	44.57	......	......	0.00	−0.29	44.28	2.441	22.7°	23.0°
20 000...	1 27	34.70	80.69	45.99	......	......	+0.59	−0.33	46.25	2.312	22.7°	23.0°

Distance of scale = 246 cm.

C. A. P. Turner, Observer. A. Zeleny, Operator.

Remarks.—It will be noticed that these readings run quite regularly, the first a trifle high, perhaps, due in part to an observational error, and in part to the fact that the thermo-pile was affected by the lighting of the jets used for reading the scale. This effect would gradually disappear, the source of heat being constant.

The first reading was not in the center of the scale, and for that reason the galvanometer corrections are probably too small for loads of 14 000 lbs. and over.

It will be noted that the point where the curve changes has not been materially raised by the load applied.

Experiment 4.

Evening, August 9th, 1901.

Bar No. 1 (*Continued*).—Strained to 24 000 lbs. Small thermo-pile and Knott galvanometer. Small Olsen machine used.

Load.	Time, seconds.	First reading.	Second reading.	Deflection.	Corrections: Resistance.	Temperature.	Rad. corrected to 22'.	Galvanometer.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Rod.	Room.
8 250...	30	62.41	53.40	9.01	−0.02	+0.01	....	−0.07	8.93	1.082	22.5°	23.5°
5 940...	29	62.22	55.58	6.64	......	.....	....	−0.02	6.64	1.118	22.7°	24.0°
8 070...	28	62.22	55.39	8.83	......	.....	....	−0.06	8.77	1.087	....	....
6 900...	29	62.10	54.30	7.80	......	.....	....	−0.04	7.76	1.124	....	....
10 200...	29	62.34	50.87	11.47	......	.....	....	−0.15	11.32	1.110	....	....
10 000...	29	62.22	50.99	11.23	......	.....	....	−0.14	11.09	1.109	....	....
12 000...	29	62.20	48.80	13.40	......	.....	....	−0.22	13.18	1.098	....	....
12 000...	29	62.55	48.88	13.69	......	.....	....	−0.23	13.46	1.122	....	....
13 000...	32	62.39	47.68	14.71	......	.....	....	−0.27	14.44	1.111	23.7°	24.5°
15 000...	29	62.39	45.41	16.98	......	.....	....	−0.39	16.59	1.106	....	....
17 110...	30	62.50	43.02	19.48	+0.02	−0.02	....	−0.51	18.97	1.108	23.0°	23.6°
19 080...	29½	62.31	45.53	16.78	+0.02	−0.02	....	−0.37	16.41	0.862	....	....

Distance of scale = 249.2 cm. Resistance = 0 ohms.

C. A. P. Turner, Observer. A. Zeleny, Operator.

Remarks.—It may be noted that these readings are more irregular than can be accounted for otherwise than by the overstrain of the bar, and that the falling away of the curve from a straight line is approximately the same position as indicated in Experiment 1.

Experiment 5.

P. M., August 10th, 1901.

Bar No. 3.—Bar size = 2 x ½ in. Bar rough. Straight on one side and very slightly curved on the other. A thermo-pile on each side of the bar.

1. Large thermo-pile and Knott galvanometer.

Load.	Time.	First reading.	Second reading.	Deflection.	Corrections: Resistance.	Temperature.	Rad. corrected to 1' 8''.	Galvanometer.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Bar.	Room.
	m. s.											
6 000	1 11	45.98	52.50	6.52	......	......	+0.04	−0.02	6.52	1.087	22.0°	22.0°
10 070	1 8	46.11	56.50	10.39	......	......	0.00	−0.11	10.28	1.021	....	....
10 030	1 7	46.30	55.92	10.62	......	......	−0.02	−0.12	10.48	1.045	....	....
14 050	1 8	46.59	61.51	14.92	......	......	0.00	−0.29	14.63	1.041	22.0°	22.1°
18 040	1 0	46.70	65.12	18.42	......	......	−0.27	−0.45	17.70	0.981	....	....
19 140	1 7	46.88	66.48	19.60	+0.01	......	−0.03	−0.52	19.06	0.996	....	22.5°
20 200	0 55	46.80	67.50	20.70	+0.01	......	−0.43	−0.58	19.70	0.975	....	22.5°
20 160	1 18	47.00	67.48	20.48	+0.01	......	+0.19	−0.57	20.06	0.995	....	22.5°
22 200	1 19	47.21	71.42	23.21	+0.01	......	+0.42	−0.75	22.89	1.031	....	22.5°
24 000	1 17	47.30	73.10	25.80	+0.01	......	+0.40	−0.95	25.26	1.054	....	....
26 000	1 12	47.29	76.70	29.41	+0.01	......	+0.20	−1.26	28.36	1.091	22.1°	22.5°
28 000	1 11	47.31	78.98	31.67	+0.02	−0.01	+0.19	−1.45	30.42	1.086	....	....
30 000	1 12	47.09	80 +	32.91	+0.02	−0.01	+0.26	−1.57	31.61	1.054	22.1°	22.5°

Distance of scale = 249.2 cm. Resistance = 0 ohms.

2. Small thermo-pile and Queen galvanometer.

For headings of these columns, see previous page.

6 000	1 11	33.81	43.04	9.23	......	......	+0.06	−0.00	9.29	1.548	22.0°	22.0°
10 070	1 8	34.43	50.17	15.74	......	......	0.00	−0.02	15.72	1.561	....	....
10 040	1 7	35.21	50.70	15.49	......	......	−0.02	−0.02	15.45	1.538	....	....
14 050	1 8	30.05	51.68	21.63	......	......	0.00	−0.04	21.59	1.536	22.0°	22.1°
18 040	1 0	36.40	63.80	27.40	......	......	−0.36	−0.07	26.97	1.495	....	....
19 140	1 7	36.20	64.40	28.20	+0.01	......	−0.04	−0.08	28.09	1.462	....	22.5°
20 200	0 55	36.72	65.10	29.38	0.00	......	−0.61	−0.08	28.69	1.420	...	22.5°
20 160	1 13	37.38	65.20	27.82	+0.01	......	+0.26	−0.08	28.83	1.430	....	22.5°
22 200	1 19	37.90	68.91	30.01	+0.02	......	+0.57	−0.10	31.50	1.419	....	22.5°
24 000	1 17	38.10	69.00	30.90	+0.02	......	+0.48	−0.10	31.30	1.304	....	....
26 000	1 12	38.29	74.10	35.81	+0.02	......	+0.28	−0.16	35.95	1.383	22.1°	22.5°
28 000	1 11	38.10	77.30	39.20	+0.02	−0.1	+0.23	−0.21	39.23	1.401	....	....
30 000	1 12	37.90	77.70	39.40	+0.02	−0.1	+0.30	−0.21	39.50	1.317	22.1°	22.5°

Distance of scale = 246 cm. Resistance = 460 ohms.

C. A. P. Turner. Observer. A. Zeleny, Operator.

Remarks.—The bar, as noted, was a rough bar, and slightly kinked or bent on one side, and bending resulting therefrom may be noticed in the curve.

Experiment 6.

Evening, August 10th, 1901.

Bar No. 3 (*Continued*).—Bar stretched about 1¼ hours to 24 000. Thermo-pile on each side of bar.

1. Small thermo-pile and Queen galvanometer.

Load.	Time.	First reading.	Second reading.	Deflection.	Corrections: Resistance.	Corrections: Temperature.	Corrections: Rad. corrected to 1' 0''.	Corrections: Galvanometer.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Bar.	Temperature: Room.
	m. s.											
8 050	1 4	38.20	50.40	12.20	......	......	+0.10	−0.01	12.29	1.526	22.0°	22.8°
12 150	1 2	38.71	56.39	17.68	......	......	+0.08	−0.02	17.74	1.461	....	....
10 285	1 0	38.90	54.32	15.42	......	......	0.00	−0.02	15.40	1.497	....	....
12 340	0 57	38.50	56.50	18.00	......	......	−0.12	−0.02	17.86	1.447	....	....
18 360	0 57	38.42	63.18	24.76	......	......	−0.16	−0.06	24.54	1.336	....	....
24 100	1 0	39·32	70.3	30.98	......	−0.01	0.00	−0.10	30.87	1.281	22.1°	22.8°

Distance of scale = 249.2 cm.

2. Large thermo-pile and Knott galvanometer.

8 050	1 4	47.00	54.70	7.70	......	......	+0.06	−0.04	7.72	0.959	22.0°	22.8°
12 150	1 2	47.18	58.16	11.08	......	......	+0.05	−0.18	10.95	0.8967	....	....
10 285	1 0	47.21	56.89	9.68	......	......	0.00	−0.09	9.59	0.9766	....	....
12 340	0 57	47.42	58.81	11.39	......	......	−0.07	−0.15	11.17	0.9052	....	....
18 360	0 57	47.01	64.30	17.29	......	......	−0.11	−0.40	16.78	0.9140	....	....
24 100	1 0	47 21	68.10	10.89	......	......	0.00	−0.60	20.29	0.8454	22.1°	22.8°

Distance of scale = 246 cm.

C. A. P. Turner, Observer. A. Zeleny, Operator.

Remarks.—This bar had been strained to 35 000 lbs. per square inch and left under a load of 24 000 lbs. for 1¼ hours.

The readings were quite irregular, due to this treatment.

Experiment 7.

Evening, August 14th, 1901.

Bar No. 1 (*Continued*).—Bar annealed by heating 2 hours in oven. Thermo-pile on each side of bar. Gum arabic contact, August 12th.

1. Small thermo-pile and Knott galvanometer.

Load.	Time, seconds.	First reading.	Second reading.	Deflection.	Corrections: Resistance.	Corrections: Temperature.	Corrections: Rad.	Corrections: Galvanometer.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Bar.	Temperature: Room.	
8 180 (?)	30	43.56	57.12	13.56	....	....	Small.	—0.23	13.33	1.630	24.3°	25.0°	
8 210....	32	43.37	57.31	13.94	....	....	"	—0.25	13.69	1.675	......	......	
10 060....	30	43.54	59.59	16.05	....	....	"	—0.33	15.72	1.562	......	......	
10 185....	31	43.80	58.93	15.13	....	....	"	—0.29	14.84	1.464	......	......	
10 090....	27	43.85	54.78	10.85	....	....	"	—0.12	10.73	......	24.3°	25.0°	Contact Defective.
14 000....	31	43.72	68.84	25.12	....	....	"	—0.90	24.22	......	......	......	
12 115....	32	43.92	61.06	17.14	....	....	"	—0.40	16.74	......	......	......	
16 050....	35	44.02	62.42	18.40	....	....	"	—0.46	17.94	......	24.3°	25.0°	

Distance of scale = 249.2 cm.

2. Large thermo-pile and Queen galvanometer.

8 180 (?)	30	28.97	45.73	16.76	....	....	Small.	—0.02	16.74	2.046	24.3°	25.0°.....
8 210....	32	29.50	46.02	16.70	....	....	"	—0.02	16.68	2.032	......	....
10 060....	30	30.00	50.34	20.34	....	....	"	—0.03	20.31	2.019	......	....
10 185....	31	30.27	50.46	20.19	....	....	"	—0.03	20.16	1.979	......	....
10 090....	27	30.05	50.45	20.40	....	....	"	—0.03	20.37	2.022	24.3°	25.0°.....
14 000....	31	30.33	58.29	27.96	....	....	"	—0.08	27.88	1.997	......	....
12 115....	32	30.51	54.58	24.07	....	....	"	—0.05	24.02	1.987	......	....
16 050....	35	30.68	62.02	31.34	....	....	"	—0.10	31.24	1.953	24.3°	25.0°.....

Distance of scale = 246 cm.

Turner, Zeleny and Cates.

Remarks.—The above experiment was made using gum arabic junction, and, as noted above, the contact for the small thermo-pile was found defective before the end of the reading.

Experiment 8.

Evening, August 15th, 1901.

Bar No. 1 (*Repeated*).—Rubber cement contact. Cement put on about 4 hours before experiment.

1. Small thermo-pile and Knott galvanometer on one side of bar.

Load.	Time, seconds.	First reading.	Second reading.	Deflection.	Corrections: Resistance.	Corrections: Temperature.	Corrections: Rad.	Corrections: Galvanometer.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Bar.	Temperature: Room.
8 180..	37	41.49	57.11	15.62	0.00	......	Small.	—0.31	15.31	1.871	23.8°	24.6°
10 765..	35	42.20	62.61	20.41	+0.01	......	"	—0.57	19.85	1.844	23.8°	25.0°
6 225..	37	43.30	54.24	11.92	0.00	......	"	—0.17	11.75	1.888	....	....
12 240..	40	42.71	66.94	24.23	+0.01	......	"	—0.84	23.40	1.912	....	....
13 440..	43	42.79	70.68	27.89	+0.02	......	"	—1.12	26.79	1.993	23.8°	25.1°
16 560..	44½	42.78	77.20	34.42	+0.02	......	"	—1.74	32.70	1.975	....	....
8 190..	39	42.69	60.28	17.59	+0.01	......	"	—0.41	17.19	2.099	....	....
18 100..	38	42.61	80.49	37.88	+0.02	......	"	—2.13	35.77	1.976	23.8°	25.1°
20 100..	41	42.30	85.50	43.20	+0.02	......	"	—2.75	40.47	2.013	....	....

Distance of scale = 250 cm.

2. Large thermo-pile and Queen galvanometer on other side of bar.

For headings of these columns, see previous page.

8 180..	37	47.65	63.55	15.90	0.00	......	Small.	−0.02	15.88	1.941	23.8°..	24.6°
10 765..	35	47.87	68.48	21.11	+0.01	......	"	−0.03	21.09	1.959	23.8°..	25.6°
6 225..	37	48.48	60.63	12.15	0.00	......	"	−0.01	12.14	1.950	....	....
12 240..	40	48.30	72.10	23.80	+0.01	......	"	−0.05	23.76	1.941	....	....
13 440..	43	48.32	74.95	26.63	+0.02	......	"	−0.07	26.58	1.978	23.8°..	25.1°
16 560..	44½	48.50	79.97	31.47	+0.02	......	"	−0.10	31.39	1.896	....	....
8 190..	39	48.73	65.02	16.29	+0.01	......	"	−0.02	16.28	1.988	....	....
18 100..	38	48.73	84.10	35.37	+0.02	......	"	−0.15	35.24	1.947	23.8°..	25.1°
20 100..	41	49.00	87.12	38.12	+0.02	......	"	−0.19	37.95	1.850	*.......	....

Distance of scale = 246 cm. Turner, Zeleny and Skinner.

Remarks.—This experiment on Bar No. 1 when repeated was made with rubber cement junction. As the bar had not been overstrained since it was annealed, fairly regular results should have been expected.

There appears to have been some little bending in the bar, as will be observed by comparing the readings of the two sets. The first reading of the Knott galvanometer was higher than that at which the galvanometer correction was determined, namely, 30; hence these corrections are too small. Further, it will be noticed that the first readings of the Knott galvanometer were from 41.50 to 42.30, and a similar change in the first readings of the Queen galvanometer, thus showing considerable temperature change during the experiment.

Experiment 9.

Evening, August 17th, 1901.

Bar No. 3, stretched to 38 500 lbs. at 4.30 P. M., August 10th, and left under that stress until 5 P. M. of August 17th. Experiment began at 7.30 P. M., August 17th.

1. Small thermo-pile and Knott galvanometer. Larger Olsen testing machine used.

Small thermo-pile nearer lights, so that the readings are less accurate.
Resistance = 100 ohms.

Load.	Time.	First reading.	Second reading.	Deflection.	Corrections: Resistance.	Tempera-ture.	Rad. corrected to 1' 10".	Galvano-meter.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Bar.	Room.
	m. s.											
4 120	1 0	28.20	30.59	2.39	......	0.00	−0.04	0.00	2.35	0.5704	....	....
4 080	1 2	27.92	30.26	2.34	......	0.00	−0.03	0.00	2.31	0.5662	25.1°	25.2°
6 000	1 5	27.69	31.24	3.55	......	0.00	−0.03	0.00	3.52	0.5867	....	....
8 090	1 5	27.69	32.46	4.77	......	0.00	−0.04	0.00	4.73	0.5847	25.05°	25.2°
10 080	0 48	25.82*	32.01	6.19	......	0.00	−0.18	−0.01	6.00	0.5952	25.2°	25.0°
10 810	0 59	25.82	33.19	6.47	......	0.00	−0.12	−0.01	6.34	0.5865	....	....
9 900	1 18	26.72	32.50	5.89	......	0.00	+0.08	−0.01	5.96	0.6020	....	....
10 000	1 20	26.61	32.56	5.95	......	0.00	+0.10	−0.01	6.04	0.6040	24.9°	25.0°
13 120	1 7	26.58	34.37	7.79	......	+0.01	−0.05	−0.04	7.71	0.5877	....	....
16 320	1 8	26.45	36.22	9.77	......	+0.01	−0.04	−0.06	9.68	0.5931	....	....
20 235	1 6	26.31	38.56	12.25	......	+0.01	−0.08	−0.17	12.01	0.5934	....	....
24 170	1 6	26.07	40.52	14.45	−0.01	+0.01	−0.10	−0.27	14.08	0.5825	24.85°	24.8°
26 500	0 54	26.60	41.98	16.38	−0.01	+0.01	−0.38	−0.35	15.65	0.5902	....	....
30 308	1 10(?)	24.42	42.55	18.13	−0.01	+0.01	0.00	−0.44	17.69	0.5838	....	....
34 300	1 11	25.01	45.29	20.28	−0.01	+0.02	+0.03	−0.54	19.89	0.5767	24.85°	24.4°
38 350	1 5	24.42	47.30	22.94	−0.01	+0.02	−0.21	−0.74	22.00	0.5736	....	....

Distance of scale = 250 cm.

2. Large thermo-pile and Queen galvanometer.

For headings of these columns, see previous page.

4 120	1 0	44.87	49.00	4.18	......	0.00	−0.07	0.00	4.06	0.985	25.1°..	25.1°
4 080	1 2	44.73	48.83	4.10	......	0.00	−0.06	0.00	4.04	0.980	....	....
6 000	1 5	44.68	50.82	6.14	......	0.00	−0.05	0.00	6.09	1.015	25.05°	25.2°
8 090	1 5	44.54	52.78	8.24	......	0.00	−0.07	0.00	8.17	1.010	25.2°..	25.0°
10 080	0 48	43.60	54.30	10.70	......	0.00	−0.32	0.00	10.38	1.030	....	....
10 810	0 59	43.25	54.50	11.25	......	+0.01	−0.20	0.00	11.06	1.020	....	....
9 900	1 18	43.36	53.38	10.02	......	+0.01	+0.14	0.00	10.17	1.027	24.9°..	25.0°
10 000	1 20	43.30	53.38	10.08	......	+0.01	+0.17	−0.10	10.16	1.016	....	....
13 120	1 7	43.37	56.85	13.48	......	+0.02	−0.08	−0.01	13.41	1.022	....	....
16 320	1 8	43.19	59.90	16.71	......	+0.02	−0.07	−0.02	16.64	1.020	....	....
20 235	1 6	43.17	63.83	20.66	−0.01	+0.02	−0.14	−0.03	20.49	1.013	....	....
24 170	1 6	43.07	67.40	24.33	−0.01	+0.02	−0.17	−0.05	24.12	0.998	24.85°.	24.8°
26 500	0 54	43.10	71.40	28.30	−0.01	+0.02	−0.67	−0.08	27.56	1.040	....	....
30 308	1 10(?)	42.20	72.55	30.35	−0.01	+0.03	0.00	−0.09	30.28	0.999	....	....
34 300	1 11	42.08	73.50	31.42	−0.01	+0.08	+0.05	−0.10	31.39	0.915	24.85°.	24.4°
38 350	1 5	42.10	79.90	37.80	−0.01	+0.04	−0.34	−0.19	37.30	0.972	....	....

Distance of scale = 24.6 cm. Resistance in box = 760 ohms. Bar No. 8 broken at 64 200 lbs.

C. A. P. Turner, A. Zeleny.

In this experiment it would seem probable that the effect of the treatment has been to reduce the cooling effect for all loads.

* A gas jet 12 ft. away caused the galvanometer needle to move 7 mm. in about 2 minutes, through three thicknesses of carpet. First reading changed from effect of this.

Experiment 10.

Evening, August 22d, 1901.

Bar No. 5. Surface planed. Area of bar = 0.445 × 2 ins. = 0.890 sq. in. Large thermo-pile and Queen galvanometer. Large Olsen machine used.

Load.	Time.	First reading.	Second reading.	Deflection.	Corrections:				Corrected deflection.	Deflection per 1 000 lbs.	Temperature:	
					Resistance.	Tempera-ture.	Rad. corrected to 1' 0".	Galvano-meter.			Bar.	Room.
	m. s.											
6 040	1 0	46.00	54.64	8.64	......	......	0.00	−0.00	8.64	1.430	Assumed constant.	25.05°
8 000	1 1	46.00	57.44	11.44	......	......	+0.02	−0.00	11.46	1.433		......
12 000	1 3	46.36	63.36	17.20	......	......	+0.11	−0.02	17.29	1.441		*25.05 °
15 520	1 11	46.67	68.39	21.72	......	......	+0.48	−0.08	22.12	1.425		......
16 040	0 55	46.53	69.89	23.36	......	......	−0.23	−0.05	23.08	1.439		......
15 825	0 57	46.58	69.59	23.01	......	......	−0.16	−0.05	22.80	1.441		......
17 600	0 55	42.42	72.96	26.26	......	0.00	−0.27	−0.06	25.93	1.473		......
20 020	0 54	46.28	75.19	29.11	......	0.00	−0.35	−0.08	28.68	1.433		25.0°
22 000	1 1	46.00	76.73	30.73	......	+0.01	+0.05	−0.09	30.70	1.395		......
24 000	1 0	45.90	79.40	33.50	......	+0.01	0.00	−0.14	33.37	1.390		......
25 000	1 0	45.68	81.21	35.53	......	+0.01	0.00	−0.16	35.38	1.415		......
24 200	0 59	45.55	79.78	34.23	......	+0.01	−0.07	−0.14	34.03	1.406		......
28 100	1 3	45.41	81.10	35.69	......	+0.01	+0.23	− 0.16	35.77	1.273		......

* Application of load too slow at first weight?

Distance of scale = 250 cm. Resistance in box = 400 ohms.

C. A. P. Turner, A. Zeleny.

Experiment 11.

Evening, August 26th, 1901.

Bar No. 5 (*Repeated*).—Bar strained to 28 000 lbs. on August 22d.

1. Small thermo-pile and Knott galvanometer.

Load.	Time.	First reading.	Second reading.	Deflection.	Corrections: Resistance.	Corrections: Tempera-ture.	Corrections: Rad. corrected to 1' 10''.	Corrections: Galvano-meter.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Bar.	Temperature: Room.
	m. s.											
6 050..	1 26	31.60	36.21	4.61	......	......	+0.11	0.00	4.72	0.7801	23.4°	24.0°
9 865..	1 15	32.56	39.94	7.38	......	......	+0.07	—0.03	7.42	0.7522	....	....
10 065..	1 12	32.68	40.39	7.71	......	......	+0.03	—0.04	7.70	0.7650	23.4°	24.0°
6 078..	1 8	32.81	37·65	4.84	......	......	—0.02	0.00	4.82	0.7936	....	....
10 000..	1 13	32.80	40.29	7.49	......	......	+0.04	—0.03	7.50	0.7500	....	....
14 062..	1 0	32.35	43.00	10.65	......	......	—0.18	—0.12	10.35	0.7361	23.4°	24.0°

Distance of scale = 250 cm. Resistance in box = 130 ohms.

2. Large thermo-pile and Queen galvanometer.

Load.	Time.	First reading.	Second reading.	Deflection.	Corrections: Resistance.	Corrections: Tempera-ture.	Corrections: Rad. corrected to 1' 10''.	Corrections: Galvano-meter.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Bar.	Temperature: Room.
6 050..	1 26	43.00	49.21	6.21	......	......	+0.15	0.00	6.36	1.026	23.4°	24.0°
9 865..	1 15	43.68	54.75	11.07	......	......	+0.10	—0.00	11.17	1.132	....	....
10 065..	1 12	44.22	56.35	12.13	......	......	+0.05	—0.01	12.19	1.184	23.4°	24.0°
6 078..	1 8	44.62	50.49	5.87	......	......	—0.02	0.00	5.85	0.963	....	....
10 000..	1 13	45.22	57.28	12.06	......	......	+0.07	—0.01	12.12	1.212	....	....
14 062..	1 0	45.70	62.17	16.47	......	......	—0.28	—0.12	16.17	1.150	23.4°	24 0°

Distance of scale = 246 cm. Resistance in box = 460 ohms.

C. A. P. Turner, A. Zeleny.

Experiment 12.

Evening, August 27th, 1901.

Bar No. 7.—Area of bar = 0.440 × 1.68 ins. = 0.739 sq. in.

1. Small thermo-pile and Knott galvanometer.

Load.	Time.	First reading.	Second reading.	Deflection.	Corrections: Resistance.	Corrections: Tempera-ture.	Corrections: Rad. corrected to 1' 10''.	Corrections: Galvano-meter.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Bar.	Temperature: Room.
	m. s.											
8 000..	1 15	32.71	40.90	8.29	......	......	+0.08	—0.05	8.32	1.040	24.48°	24.8°
6 010..	1 16	32.82	38.69	5.87	......	......	+0.06	—0.01	5.92	0.985	24.48°	24.8°
9 700..	1 12	32.44	42.50	10.06	......	......	—0.04	—0.10	9.92	1.033	....	....
14 230..	1 7	32.25	49.84	14.84	......	......	—0.09	—0.28	14.47	1.017	....	....
16 000..	1 6	32.09	48.50	16.41	......	......	—0.10	—0.36	15.95	0.997	24.50°	24.8°
17 000..	1 10	31.99	49.45	17.46	......	......	0.00	—0.41	17.05	1.003	....	....
20 000..	1 10	31.72	52.30	20.68	......	......	0.00	—0.58	20.10	1.005	....	....
22 000..	1 15	31.50	53.30	21.80	......	......	+0.20	—0.68	21.32	0.973	24.49°	24.7°

Distance of scale = 250 cm. Resistance in box = 130 ohms.

2. Large thermo-pile and Queen galvanometer.

For headings of these columns, see previous page.

8 000..	1 15	46.32	57.67	11.35	......	......	+0.10	0.00	11.45	1.431	24.48°	24.48
6 010..	1 18	46.48	55.02	8.54	......	......	+0.12	0.00	8.66	1.441	24.48°	24.8°
9 700..	1 14	46.55	60.22	13.67	......	......	+0.10	—0.01	13.76	1.419	....	....
14 280..	1 7	46.25	66.52	20.27	......	......	—0.12	—0.03	20.12	1.414	....	....
16 000..	1 8	46.30	68.10	21.80	......	......	—0.09	—0.04	21.67	1.354	24.50°	24.8°
17 000..	1 10	46.00	69.76	23.76	......	......	0.00	—0.05	23.71	1.395	....	....
20 000..	1 10	45.90	73.02	27.12	......	......	0.00	—0.07	27.05	1.352	....	....
22 000..	1 15	45.40	74.28	28.88	......	......	+0.26	—0.68	29.06	1.321	24.49°	24.70°

Distance of scale = 246 cm. Resistance in box = 460 ohms.

C. A. P. Turner, A. Zeleny.

The temperature conditions during this experiment were not very satisfactory.

Description of Bar No 7: L2-4734, Boiler. Surfaces planed. Elastic limit = 41 000 lbs. Ultimate strength = 57 500 lbs. Elongation = 28½% in 8 ins. Analysis: Carbon, 0.21. Manganese, 0.38. Phosphorus, 0.033. Sulphur, 0.022.

This bar was strained up to the yield point in 1897, and had been allowed to rest until the date of the experiment, and the thermal limit of proportionality did not appear to have been raised.

EXPERIMENT 13.

Evening, August 29th, 1901.

Bar No. 8. Area of Bar = 0.433 × 1.62 ins. = 0.701 sq. in.

1. Small thermo-pile and Knott galvanometer.

Load.	Time.	First reading.	Second reading.	Deflection.	Corrections: Resistance.	Corrections: Temperature.	Corrections: Rad. corrected to 1' 18".	Corrections: Galvanometer.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Bar.	Temperature: Room.
	m. s.											
6 040	1 26	33.00	37.95	4.95	....	....	+0.06	0.00	5.01	0.829	23.5°	23.8°
8 100	1 17	33.13	39.87	6.74	....	....	—0.01	—0.02	6.71	0.827	.....	.....
10 060	1 21	32.79	41.14	8.35	....	....	+0.04	—0.05	8.34	0.829	.....	.....
11 780	1 16	32.60	42.51	9.91	....	....	—0.03	—0.10	9.78	0.8302	23.5°	23.7°
13 670	1 18	32.50	43.70	11.20	....	....	0.00	—0.14	11.06	0.8095	.....	.....
15 950	1 29	32.30	45.41	13.11	....	....	+0.21	—0.20	13.12	0.8226	.....	.....
18 000	1 19	32.19	46.65	14.46	....	....	+0.02	—0.27	14.21	0.7894	.....	.....
21 000	1 15	32.09	49.10	17.01	....	....	—0.09	—0.39	16.53	0.7871	23.5°	23.4°

Distance of scale = 250 cm. Resistance = 130 ohms.

2. Large thermo-pile and Queen galvanometer.

6 040	1 26	43.30	50.80	7.50	....	....	+0.09	0.00	7.59	1.256	23.5°	23.8°
8 100	1 17	43.50	53.82	10.32	....	....	—0.02	0.00	10.30	1.271	.....	.....
10 060	1 23	43.31	56.02	12.71	....	....	+0.11	—0.01	12.81	1.273	.....	.....
11 780	1 19	43.06	58.11	15.05	....	....	+0.02	—0.02	15.05	1.278	23.5°	23.7°
13 670	1 19	42.88	59.60	16.72	....	....	+0.02	—0.02	16.72	1.223	.....	.....
15 950	1 29	42.79	62.20	19.41	....	....	+0.32	—0.03	19.70	1.235	.....	.....
18 000	1 19	42.69	64.02	21.33	....	....	+0.03	—0.03	21.33	1.185	.....	.....
21 000	1 16	42.59	67.64	25.05	....	....	—0.08	—0.06	24.91	1.186	23.5°	23.4°

Distance of scale = 246 cm. Resistance = 760 ohms.

C. A. P. Turner, A. Zeleny.

Description: 4794 Fire-box L3. Elastic limit, 39 500 lbs. Ultimate strength, 59 000 lbs. Elongation, 28.7 per cent.

Analysis: Carbon.................. 0.21 Phosphorus.................. 0.035
Manganese.............. 0.35 Sulphur...................... 0.028

This bar also had been pulled to the yield point in 1897, and the load had been left applied for two days at that time, but the thermal limit of proportionality did not appear to have been been raised after this period of rest.

Experiment 14.

P. M., August 31st, 1901.

Bar No. 6. Planed. Area of Bar = 0.440 × 2 ins. = 0.880 sq. in.

1. Small thermo-pile and Knott galvanometer.

Load.	Time.	First reading.	Second reading.	Deflection.	Corrections: Resistance corrected to 20.5°.	Temperature.	Rad. corrected to 1' 15".	Galvanometer.	Corrected deflection.	Deflection per 1 000 lbs.	Temperature: Bar.	Room.
	m. s.											
6 175	1 20	35.00	38.10	3.60	—0.01	......	+0.03	0.00	3.62	0.586	19.4°	19.5°
7 760	1 15	36.55	41.09	4.54	—0.02	......	0.00	0.00	4.52	0.583	19.5°	19.9°
10 095	1 19	37.84	43.70	5.86	—0.01	......	+0.04	—0.01	5.90	0.584	19.5°	20.0°
14 040	1 19	39.97	48.24	8.28	—0.01	......	+0.06	—0.05	8.28	0.5897	19.6°	20.3°
16 050	1 15	40.68	49.93	9.25	......	......	0.00	—0.07	9.18	0.5719	19.8°	20.5°
17 800	1 18	40.65	50.95	10.30	......	......	+0.06	—0.10	10.26	0.5764	19.8°	20.6°
19 800	1 14	40.27	51.94	11.67	......	......	—0.02	—0.15	11.50	0.5808	19.8°	20.5°
21 950	1 17	40.41	53.41	12.87	......	......	+0.05	—0.19	12.73	0.5800	19.8°	20.5°†
23 700	1 16	40.76	54.80	14.04	......	......	+0.02	—0.25	13.81	0.5827	19.8°	20.5°
25 700	1 20	40.81	55.98	15.17	......	......	+0.13	—0.29	15.01	0.5840	19.8°	20.5°
28 000	1 18	40.90	57.42	16.52	......	......	+0.09	—0.33	16.28	0.5814	19.85°	20.5°
31 000	1 16	41.04	59.88	18.84	......	......	+0.08	—0.45	17.92	0.5781	19.80°	20.5°
18 610	1 15	40.22	50.94	10.72 *	......	......	0.00	—0.10	10.62	0.5706	19.9°	20.5°
34 000	1 18	41.05	61.08	20.03 *	+0.01	—0.01	+0.11	—0.54	19.60	0.5735	19.9°	20.6°

* Evening. † Chuck slipped.

Distance of scale = 250 cm. Resistance = 0 ohms.

2. Large thermo-pile and Queen galvanometer.

6 175	1 21	35.54	43.20	7.67	......	......	+0.07	0.00	7.73	1.252	19.4°	19.5°
7 760	1 14	43.15	53.01	9.86	......	......	—0.01	0.00	9.85	1.269	19.5°	19.9°
11 095	1 18	44.02	56.70	12.68	......	......	+0.09	—0.01	12.76	1.264	19.5°	20.0°
14 040	1 19	45.785	63.18	17.395	......	......	+0.12	—0.02	17.495	1.246	19.6°	20.3°
16 050	1 14	46.33	66.25	19.92	......	......	—0.03	—0.03	19.86	1.237	19.8°	20.5°
19 800	1 14	46.23	70.87	24.64	......	......	—0.04	—0.06	24.54	1.239	19.8°	20.6°
21 950	1 15	46.08	73.63	27.55	......	......	0.00	—0.07	27.48	1.252	19.8°	20.5°
23 700	1 13	46.12	75.20	29.08	......	......	—0.11	—0.08	28.89	1.219	19.8°	20.5°†
25 700	1 15	45.92	77.30	31.38	......	......	0.00	—0.10	31.28	1.217	19.8°	20.5°
28 000	1 15	45.93	80.14	34.21	......	......	0.00	—0.14	34.07	1.217	19.85°	20.5°
31 000	1 14	46.05	83.65	37.60	......	......	—0.06	—0.17	37.37	1.205	19.80°	20.5°
18 610	1 13	45.54	68.68	23.14	......	......	—0.08	—0.05	23.01	1.236	19.9°	20.5°
34000	1 15	46.02	86.28	40.26	+0.01	—0.01	0.00	—0.22	40.04	1.177	19.9°	20.6°

Distance of scale = 246 cm. Resistance = 460 ohms.

Turner, Zeleny and Kennicott.

Remarks.—Large temperature changes. Rates of 0.02 to 0.03 had to be allowed for in most cases. Zero reading of the Knott galvanometer was high, and hence the corrections for the larger readings are too small in the upper set.

The foregoing curves are fair examples of what can be done by this method of thermal measurement under somewhat unfavorable conditions. Where a laboratory is especially fitted for thermal measurement, a more sensitive machine for weighing the loads is used, and

where suitable means are provided for applying all loads uniformly and in more nearly the same time, a probable error not greater than 1 in 2 000 to 5 000 would perhaps be a reasonable limit of accuracy.

The method has a number of advantages over any other method of measuring stress with which the writer is familiar:

First. It is necessary only to have a space of about 1 sq. in. to apply the junction, and, indeed, this space might be reduced to ½ sq. in. and secure almost equally good results; or the thermo-pile might be of special shape, long and narrow, for measuring fiber stress in columns under compression, if so desired. For the measurement of stress in railroad bridges the apparatus would appear to be very suitable. An error of $\pm$ 5 to 6% would be the probable accuracy when the effect of air currents, etc., is considered.

The angular deflection of the galvanometer might be determined in the laboratory for given intensities of stress applied to a standard bar, and, using the same apparatus in the field, with a similar junction, and with the same resistance in the circuit, the readings could be readily interpreted. Such investigation, however, would require time and patience, because, in order to secure reliable results, care must be taken that all connections are in good order, and, where the apparatus is not working nicely, some little ingenuity is required to locate the difficulty.

Where a piece of metal is subjected to compound stress (for instance, to tension in one direction and compression in another), the cooling effect of the tensile strain will be offset by the heating effect of the compressive stress, and the reading would evidently indicate the difference between the two.

A very interesting case of this kind of stress will be found in the examination of a plate-girder with a stiffened web. The usual textbook analysis of the internal stress in the web plate of such a girder is radically in error, and Figs. 2 and 3 present the writer's conclusions from a thermo-electric investigation of the internal stress in the small riveted girder shown in Fig. 4. The distribution of the stress through the web plate is in belts, and the position of these belts varies with the position of the stiffening angles. In the experimental girder, Fig. 4, the load was applied by a jack-screw and an I-beam lever at one end and weighed off at the other.

Referring to the analysis of internal stress in beams, in Rankine's

"Applied Mechanics," it is found that the case examined by him is that of a beam of constant section along its length. For such a beam he proves clearly that the principal stresses at the neutral axis are tensile and compressive, acting at 45° with this axis and at 90° with each other.

The special case, of a beam of a given type of cross-section, increasing or decreasing regularly in section along its length, is amenable to similar mathematical analysis, and the general distribution of the internal stress would vary but slightly from the first case considered, as stated in the "Applied Mechanics."

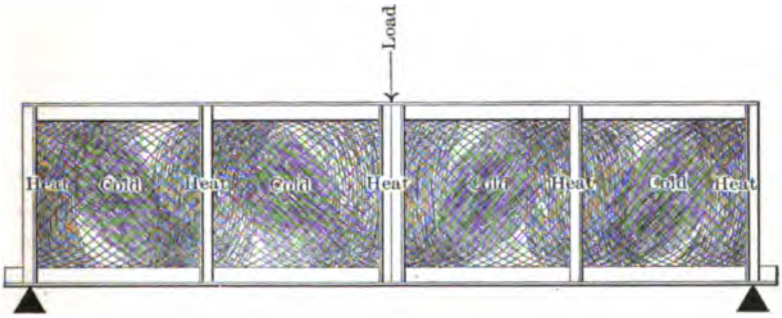


Fig. 2.

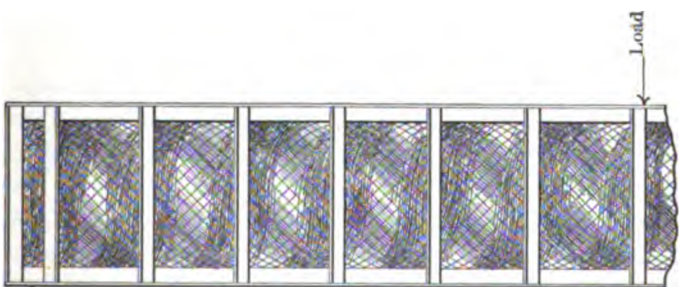


Fig. 3.

The general case, of a beam varying irregularly along its length, both as regards area and type of section, is quite a different problem, involving too many conditions to be handled in a general way. Even the special cases, when the variations are at regular intervals, with a constant section between, are by no means simple or easily analyzed.

Since built sections, when well riveted, act under stress approxi-

mately as solid sections, the built girder with stiffeners should be considered as coming under beams of the latter class, and the writer would subdivide such girders into general classes as follows:

Class 1.—Those girders in which the stiffeners are spaced economically; that is, sufficiently close to prevent buckling of the web, and causing it to be capable of fully developing the strength of the flange.

Class 2.—Those girders in which the stiffeners are placed needlessly close together.

Class 1 includes those girders in which the designer has followed Cooper's specification, in which he requires stiffeners to be placed about the depth of the girder apart when the shearing stress on the web exceeds that allowed by the formulas given.

Referring to Fig. 2, it will be noted: (1) that the lines of maximum compressive stress in the web are concentrated, as it were, in the dark area near the stiffeners, and that they have changed in direction from 45°, being deflected toward that portion of the plate best able to resist compression by virtue of the lateral support of the stiffener angles; (2) that the path over which the maximum stresses act is but slightly longer than it would be were the tensile and compressive stresses acting at 45° with each other; and (3) it is evident that the intensity of the stresses in the dark area in excess of those in the other portion of the plate is a direct function of the size of the panel, and an inverse function of the thickness of the plate.

Were the stiffeners applied vertically, and so close together that the web is practically stiffened all over, it would undoubtedly be in a condition of internal stress similar to that of the plate of a flitched beam, which the common theory covers exactly. For cases between this extreme condition of excessive stiffening and that of stiffeners spaced economically, as investigated, intermediate conditions of internal stress would naturally be expected. A solution will be offered for one only of these, as giving a fair insight to the treatment proposed for other cases.

Referring now to observations 1 and 2, concerning the distribution of stress shown in Fig. 2, these deductions may be summarized in the statement that a load seeks the shortest course consistent with the strongest members, or parts.

Referring now to Fig. 3, as in Fig. 2, the belts or areas of maximum compression would be expected near the stiffener, and slightly inclined

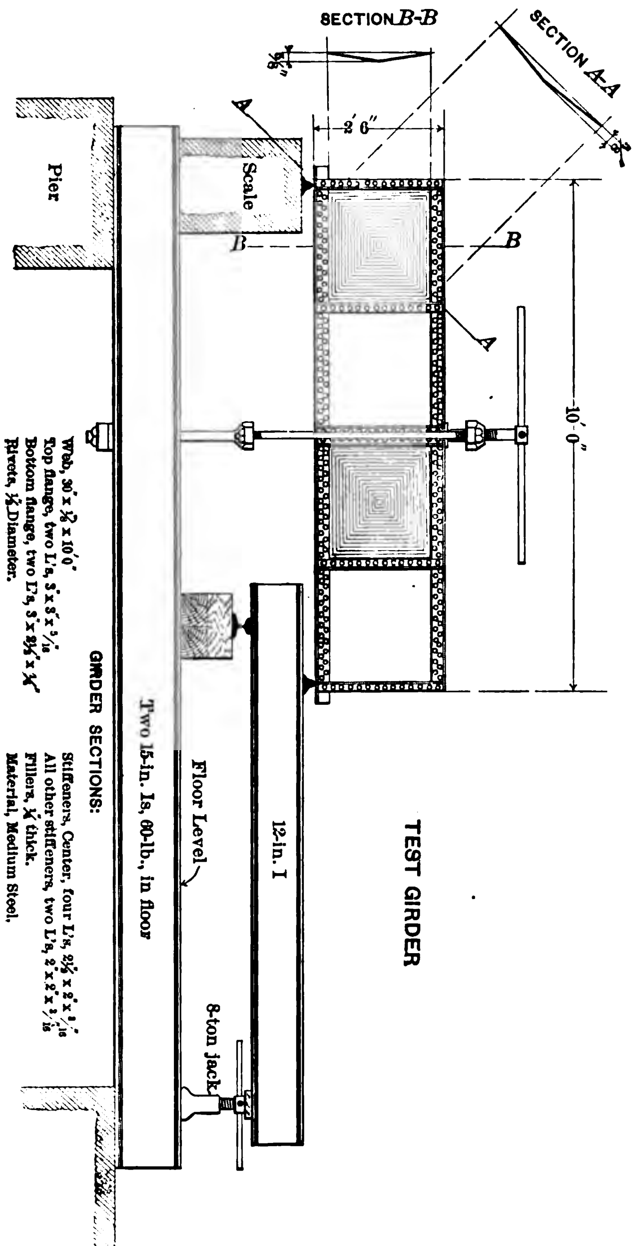

SECTION B-B
SECTION A-A
2' 6"
10' 0"
Pier
Scale
TEST GIRDER
12-in. I
Floor Level
Two 15-in. Is, 60-lb., in floor
8-ton jack
GIRDER SECTIONS:
Web, 30" x 3/8 x 10' 0"
Top flange, two L's, 3" x 3" x 5/16
Bottom flange, two L's, 3" x 2½" x ¼"
Rivets, ⅝" Diameter.
Stiffeners, Center, four L's, 2½ x 2" x 5/16
All other stiffeners, two L's, 2" x 2" x 3/16
Fillers, ¼" thick.
Material, Medium Steel.

FIG. 4.

[illegible] maximum tension, which act in connection with [illegible] the condition of following that path which [illegible] vertical deflection of the structure would nat- [illegible] alternate panel point, this being the shortest path, [illegible] with the condition named, that will allow the maximum compressive stresses to follow those portions of the plate which by the lateral support of the stiffeners is best able to resist them.

The point of most interest in this case, with a distribution of stress as outlined, would be that the stiffener would be strained much less than in the first case, Fig. 2, since the stiffener does not follow the center line of either belt of maximum stress, but, lying between them, the component of the distortion of the compressive belt along the length of the stiffener is offset in a measure by that of the tensile belt of maximum stress across it at the center.

The action of the stiffener in affecting the distribution of stress in the web may be regarded as two-fold:

First. In rendering the plate in its vicinity better able to resist compressive stress through the lateral support it affords, thus causing an uneven distribution of stress in the web, as shown in Fig. 2.

Second. Under favorable conditions, it may relieve the web of a considerable portion of the compressive web stress.

For the former action, few rivets are required, but to act efficiently in the latter capacity, where the stiffeners are economically spaced, they should be well riveted.

The effect of this distribution of the web stress in belts should, in the writer's judgment, be taken into consideration in proportioning the flanges, particularly where the girders are short and deep, and, furthermore, in deciding on the spacing of the rivets.

Measurements by Method B.—When a bar is loaded, the elastic distortion is opposed and limited by the internal molecular forces; in other words, it is said that the internal and external forces are in equilibrium. This at once conveys the conception of a different general or average distribution of internal stress between the molecules and groups of molecules along different axes, dependent on the direction of the external constraining force, and the question naturally arises whether the material will present different properties along different axes by which we may measure nearly or approximately this induced condition of internal strain.

Thomson has answered this question, partially, at least, by showing that the thermo-electric quality of iron, under pressure, deviates from that of the unstrained metal toward bismuth for currents in the direction of the strain, and toward antimony for currents perpendicular to this direction. While other metals examined by him—zinc, brass, copper and steel—showed uniformly the reverse effect to that of iron when similarly treated.*

If the position of a bar in the thermo-electric series is changed by strain, then this change may be detected by clamping to the strained bar a piece of similar unstrained metal and forming a circuit between the two bars, within which a galvanometer may be placed to measure the thermo-electric current generated by heating the junction of the two pieces of metal. Then, if the change is proportional to the load or the strain on the bar, or bears a known relation to it, this provides the necessary means of measuring the stress.

The writer's first attempt to measure stress in this way was made as follows: A 2 x ½-in. bar was placed in the testing machine, and another similar bar was clamped to it at right angles or horizontally, using a wood clamp. To the upper end of the bar in the machine was attached a steel wire, by wrapping a few turns about the bar and clamping with an iron clamp. Another steel wire was attached in a similar manner to the end of the horizontal bar, and both wires were then connected with the Queen D'Arsonval galvanometer.

The junction of the two bars was then heated with a bag of hot water, the bag being wrapped around the junction. This caused no deflection whatever, there being no load on the bar. Upon applying a load of 15 000 lbs. gradually, there was noted a gradual deflection of 1½ mm., which disappeared as the load was removed.

As this deflection was much too small to be satisfactory, an endeavor was made to get a larger deflection by using a Thomson astatic galvanometer, instead of the D'Arsonval, but the instrument was so badly disturbed by the ground currents induced by the street-railway lines as to be entirely useless. Thus, the only thing that remained to do was to either put in a coil of less resistance in the D'Arsonval galvanometer or apply more heat to the junction.

The former would have been the desirable thing to do, as it would

* *Proceedings*, Royal Society, London, 1854-55. *Philosophical Transactions*, Royal Society, London, 1855-56.

have secured accurate work, and would have cost only about $15. The time required to get the coil, however, about three weeks, caused the the writer to use the latter alternative.

Wrapping the junction with asbestos paper, it was heated up to about 180° with a gas jet, and allowed to cool to about 150° or thereabouts. Heating the junction with the bar under no load caused no deflection, but as soon as the load was applied a deflection was secured roughly in proportion to the load, for the loads up to about 18 000 or 22 000 lbs. per square inch, beyond which the increase in deflection was at a far smaller ratio than the increase in the load.

The results secured are given in part in the following tests. In considering them it should be borne in mind that the junction was gradually cooling by radiation, and the extent of the rate may be determined roughly by the slight change in deflection for the smaller loads applied at the latter part of the tests. These tests are very easy to make, requiring less than 5% of the time necessary for direct thermal measurement. The essential element necessary for satisfactory work is a constant source of heat for the junction, and securing a similar piece of metal to that which is being investigated, to form the junction.

Set 1.

Load.	Deflection:			Rate per 1 000 lbs.
	Load applied.	Load removed.	Average.	
11 100..............	0.63	0.58	0.605	0.0575
21 000..............	0.70	0.70	0.70	0.0334
22 100..............	0.60	0.82	0.71	0.0322
10 150..............	0.47	0.70	0.583	0.0574
31 000..............	0.90	1.00	0.95	0.0306
10 750..............	0.57	0.58	0.575	0.0534

C. A. P. Turner, Observer.

Set 2.

12 000..............	0.50	0.43	0.465	0.0388
23 200..............	0.66	0.68	0.67	0.0291
30 000..............	0.84	0.82	0.83	0.0276
14 200..............	0.46	0.61	0.53	0.0378
38 000..............	0.84	0.90	0.87	0.0229

A. Zeleny. Observer.

Set 3.

16 000..............	0.51	0.51	0.51	0.051
12 000..............	0.60	0.60	0.60	0.050
15 000..............	0.73	0.76	0.75	0.050
19 000..............	0.1	1.01	1.005	0.053
23 360..............	1.05	1.05	1.05	0.045

C. A. P. Turner, Observer.

The readings of Set 3 are unquestionably the most reliable, as the bars had had time to become of nearly a uniform temperature, which may perhaps account for the higher point at which the rate of deflection decreases.

These few crude experiments should not, however, be taken as a basis for definite conclusions, further than that the method appears to be practicable, though requiring considerable careful work to place it on an equally satisfactory basis with that by direct thermal measurement.

This method, which has been classed as "B" in the early part of the paper, like method "A," appears to throw an interesting light on the change in molecular structure of the metal, under such stresses as exceed well-defined limits. As the temporary strain changes the thermo-electric quality of the material, so also does a permanent strain, but the residual effect of the permanent strain or set is the reverse of that which subsists as long as the constraining force is kept applied.

Thomson concludes that the peculiar thermo-electric qualities thus induced are those of a crystal. Thus, he finds that iron bars hardened by longitudinal compression have the reverse thermo-electric property to that discovered by Magnus in wires hardened by drawing, and that iron under lateral compression manifests the same thermo-electric property that he had discovered in an iron wire under a longitudinal stretching force.

Having noted the characteristics of the change in the molecular structure of the material, caused by severe stress, it may naturally be inquired, at what intensity of stress this change commences. It has been noted that it becomes very apparent whenever the load has been sufficient to give the metal a permanent set, and, as such yielding is invariably accompanied by the evolution of heat, the inference is natural that the commencement of this change in structure begins when the thermal curve ceases to be a straight line.

When the repetitions of severe stresses are of one kind only, it may be conceived that there is a gradual change in the structure of the bar of a somewhat homogeneous character, with the ultimate result that the life of the piece would be long under Wohler treatment. But, on the other hand, where the range of stress is from tension to compression, since the residual effects of the two kinds of severe stress are

[illegible] under, a correspondingly shorter life, due to the lack of [illegible] in the change in structure by the two kinds of severe [illegible] should be expected.

What is the nature of this residual effect or change of the molecular structure? It has been noted that the temporary effect of mechanical strain of lower intensity is to change the thermo-electric property of the metal, and, apparently with reason, it has been attributed to

THERMAL STRESS CURVES
BEFORE AND AFTER OVER-STRAIN.

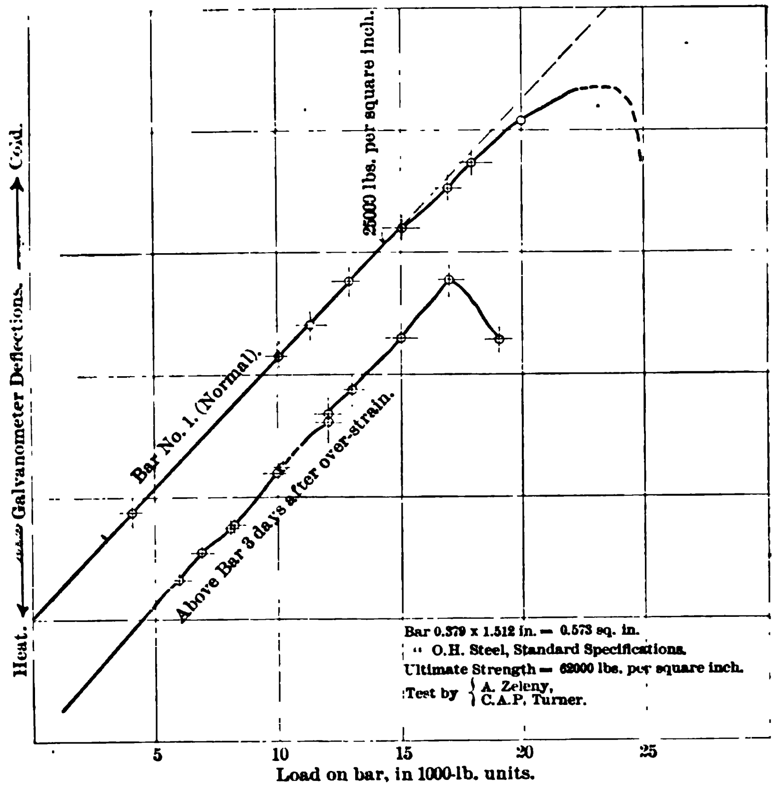


FIG. 5.

an unequal distribution of the inter-molecular forces opposing the external forces. Arguing, then, that similar effects are produced by similar causes, these residual effects may perhaps be attributed to a condition of permanent internal strain along certain lines or axes, the natural result of which would enable it more readily to resist stress of the kind which produced this condition, while, at the same time ren-

dering it weaker in other directions, less elastic or resilient and more likely to be fractured by shock or sudden loading.

In concluding this paper, a few general remarks regarding the elastic condition of the metal investigated may not be amiss, and a careful consideration of the curves presented in Fig. 5 will give a fair idea of the results to be expected under ordinarily careful work, depending upon whether the specimen is in a truly normal or unstrained condition, or whether the internal structure has been disturbed by recent overstrain. If the latter condition is that with which we have to deal, regularity of results cannot be expected, and the writer's work gives some ground for supposing that there is a slight difference in the amount of the cooling effect due to the stretching, for nearly all loads, it being less in cases where the material has been overstrained.

In the tests presented, less attention has been paid to the condition of the bars than in determining the most practical type of junction to use. Further, the writer regards the behavior of a galvanometer under a load continuously applied as a somewhat more satisfactory indication of its elastic properties than the measurements which may be taken consecutively and presented as has been done in the tests given herein.

The writer takes pleasure in acknowledging the assistance received in the experimental work from Mr. Anthony Zeleny, Instructor in Physics at the University of Minnesota, and from Messrs. F. G. Skinner, A. T. Fay, H. A. Kennicott and F. E. Cates.

Vol. XXVIII. JANUARY, 1902. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852

PAPERS AND DISCUSSIONS.

A GRAPHICAL METHOD FOR THE SOLUTION OF STRESSES IN THE CONTINUOUS GIRDER, AS APPLIED TO DRAW-BRIDGES.

Discussion.*

By George F. Barton, Esq.

Mr. Barton. George F. Barton, Esq. (by letter).—Mr. Lindenberger gives another method by means of which the moments and shears in the continuous girder may be found graphically. The writer has not been able to obtain copies of the *Journal* of the Franklin Institute, referred to in explanation of this method, and, therefore, could not follow it throughout. The method seems to be very complete, but every change in the position of the loading, or the style of the loading, necessarily changes his diagrams. It was for this reason that the writer did not go any farther in his own method.

In the method described in the paper it is only necessary to lay out one diagram once for all spans of equal arms, no matter what kind of loading may be on the structure, or what length the arms may be. For complicated structures, like draw-bridges and arches, most designers would be glad to be able to find the reactions by a simple method, and would not care to get the moments and shears, if, by doing so, they were compelled to do more work than would be required to compute them analytically, after having found the reactions graphically by a simple method. This is the writer's excuse for giving a solution, which, as a graphical solution, is incomplete.

*Continued from December, 1901, *Proceedings*. See October, 1901, *Proceedings* for paper on this subject by George F. Barton, Esq.

Mr. La Chicotte recognizes the value of this method, from this point of view, and shows that, while the ordinary assumptions may be very far out of the way, engineers seem to be afraid to use a graphical method which will save them considerable time and worry, and yet which will, in all probability, give results which are as close to the actual stresses as if there were a good deal of refinement in the calculations. Mr. Barton.

Mr. La Chicotte's very simple explanation of the deflections of beams under different loadings is very interesting, and shows clearly how a little settlement of the supports, or a change in the temperature of the chords, may change the stresses considerably.

Vol. XXVIII. JANUARY, 1902. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

A PROPOSED SOLUTION OF SOME HYDRAULIC PROBLEMS.

Discussion.*

By Messrs. I. P. CHURCH and CHARLES H. TUTTON.

Mr. Church. I. P. CHURCH, Assoc. Am. Soc. C. E. (by letter).—The author has evidently adopted as the basis of treatment the "laminar hypothesis," or assumption of flow in plane layers parallel to the bed (in this case of uniform motion of water in a rectangular channel of great width), each layer moving parallel to the bed with a constant velocity, $v_0 + v$; where v_0 is the velocity of the bottom layer (or "filament") and v the excess of the velocity of any layer over that of the bottom layer. It is well known that this hypothesis gives but an imperfect representation of the reality, but it has, nevertheless, been adopted by many writers as a convenient rude approximation to the facts.

It is, of course, a rigorous consequence of this hypothesis, by the laws of mechanics, that the layer of maximum velocity must be at the surface of the water unless there is an up-stream wind (*i. e.*, up stream relatively to the surface layer, which is itself in motion); also that the internal fluid pressure is constant at any given depth, z below the surface, so that the end-pressures, parallel to the bed, on the two ends of a portion of a layer, of length l and width unity, are equal, leaving the component (parallel to the bed) of the weight of this portion to balance the (difference between) frictions exerted on this body by the adjacent layers. Since the motion of this portion of a layer is uniform

* Continued from December, 1901, *Proceedings*. See November, 1901, *Proceedings*, for paper on this subject by Charles H. Tutton, M. Am. Soc. C. E.

and rectilinear, the components of all the forces acting on it neutralize each other, taken parallel to any axis whatever; but an axis parallel to the bed is most convenient, since it avoids bringing into play the pressures normal to the upper and lower forces of the body. Otherwise, mathematical elimination would be necessary. Mr. Church.

As regards the viscous "friction" (or shearing action due to intensity of eddying) between contiguous layers, while Navier and others consider it as proportional to the angular velocity, $\frac{d\,[v_0 + v]}{d\,z}$, or $\frac{d\,v}{d\,z}$, of a point in the upper surface of the layer with respect to a point just underneath in the lower surface of the same layer, the author assumes that it is not only proportional to that angular velocity but also to the (excess) velocity, thus following the line indicated by Bazin,* that it should be proportional to $K\frac{d\,(v_0 + v)}{d\,z}$, where K is a quantity dependent on the velocity $(v_0 + v)$.

Now, it is to be noticed that what the author calls the "first, or ordinary method" when applied to the equilibrium of the aggregation of layers (of width unity, and length l) situated between the depth, Z, of maximum velocity (where the friction is zero) and any other depth, z (where the friction is not zero) (it being assumed, for justification of the use of the laminar hypothesis, that there is an upstream wind) gives rise to the equation:

$$-F\,l + \rho\,g\,l\,(z - Z)\,s = 0 \qquad (32)$$

in which s = slope and $\rho\,g$ = weight of a unit of volume of water, while F denotes the friction per unit area on the under surface of the aggregation of layers in question, *i. e.*, at a depth, z, from the free surface of the water. This is the same as the initial equation of the author's treatment (on page 994†) and is identical with an equation established by the "ordinary method," given on page 196 of Flamant's "Hydraulique," second edition, 1900. Flamant deals with Navier's assumption for F, while Mr. Tutton assumes F of the form already indicated, and proceeds with the mathematical treatment.

It is also to be noticed that Unwin's treatment of the same problem‡ is practically identical with that of this paper (the ordinary method is used to establish a result for a single layer, which by integration is extended over any number of layers). Unwin uses the Navier form for viscosity, and at first places the maximum velocity below the surface, remarking later that if there is no resistance at the surface the maximum velocity will occur at the surface (that is, he calls attention to this rigorous outcome of using the laminar hypothesis).

Since, then, the only difference between the analysis of the author

* As quoted by Collignon in his "Hydraulique," p. 307.

† *Proceedings*, Am. Soc. C. E., for November, 1901.

‡ "Enclop. Brit." article, Hydromechanics, page 496.

Mr. Church. and that of the writers above quoted is the substitution by the former of a special viscosity factor, F, in place of the Navier form, the writer is quite unable to appreciate the alleged imperfection of the "ordinary method." In presenting what he calls "the other method," the author has brought out the familiar fact that the loss of head in the case of uniform motion in an open channel, between any two points of a given filament, is equal to the vertical distance, l sin. α, between the corresponding points in the surface of the stream; that is, it is equal to the "piezometric fall," since, for uniform motion in an open channel, the surface of the stream plays the part of a hydraulic grade line. He has also brought out the fact that the uniform motion of a filament or layer in the present problem is the same as it would be if its weight had no component parallel to the line of motion, and if (in addition) the pressure at its up-stream end parallel to the bed exceeded that at the down-stream end by an amount, $\rho\, g\, l$ sin. α, per unit of end area. To such a statement as this no reader would take exception, and probably this is all that is meant by the "Law" on page 991;* but the author's language, taken literally, would seem to indicate that in his opinion there actually is more pressure at the up-stream end of a portion of a filament than at the down-stream end; which is quite at variance with the laminar hypothesis.

While the ellipse as the vertical velocity curve is the very interesting outcome of the special viscosity assumption made by the author, the writer can see no reason why the former curve does not stand on precisely the same footing as the parabola (which is the outcome of the Navier assumption), as regards any explanation of the fact that the maximum velocity is not at the surface of the water in those cases where it should be so located if the laminar hypothesis were strictly true. Such a case is presented, for example, when the wind is down stream and has a velocity equal to that of the surface layer; under which circumstances it seems to be quite generally admitted by hydraulicians (Unwin, Flamant, Bazin, Francis, etc., etc.) that experiment shows the maximum velocity (parallel to the bed) to occur below, and not at the surface. The conclusion is inevitable that a satisfactory explanation of this fact must involve some theory of internal motion differing radically from the laminar hypothesis. Attempts at such an explanation, based on the action of eddies thrown up from the bottom, vertical currents, etc., etc., have appeared in the pages of the *Transactions* of this Society; for instance, see the paper (referred to by the author) by Mr. Francis, in Vol. VII, page 109, and the discussion following it.

Mr. Tutton. CHARLES H. TUTTON, M. Am. Soc. C. E. (by letter).—The writer wishes first to correct an error of statement into which he fell. It is stated (page 990,* etc.) that the pressure in the end of any fillet

* *Proceedings*, Am. Soc. C. E., for November, 1901.

(implying the upper end) is $\rho g l s$. This should have been $\rho g s$. Mr. Tutton.
Considering a filament, the end pressures upon it, due to exterior filaments, balance, as stated by Professor Church. In the fillet itself, when it is indefinitely shortened, $\rho g s$ may be considered a pressure applied to, as well as a component of weight of, the resulting molecule. At the lower end of a fillet, of length l, this would become $\rho g l s$. The resulting equations are not altered by this.

It may be stated that while pressure and weight are convertible terms, the writer considers weight to have no components except such as are vertical, and what by consent are called components of weight are in reality forces developed by it, which can only be defined by their effects. The idea of the paper is to confine attention to the fillet, and divest the argument of the idea of weight as measured from the free surface, which is claimed to be a necessary consequence of the laminar theory, involving the fact that the resistance at the surface must be zero.

That this latter assumption is false is shown by the fact that the maximum velocity is below the surface, even under the action of a down-stream wind. This has been shown by Boileau, Humphreys and Abbott, Cunningham, Ellis, Bazin, Price, and others. It follows, not that the atmosphere offers no resistance, but that we know very little of its character. It may be like the so-called skin of the water, and be very great as compared with the fluid resistance in the air immediately above it, but Nature shows that it exists. For this reason it has been assumed as a liquid resistance, which agrees very well with experiment. This allows an axis of maximum velocity below the surface, the depth of which depends on the relations between f and ε. In the illustrations used these were assumed equal. As a matter of fact, they are seldom equal, but whatever their relation, if they change other than in a constant ratio, the depth of axis will change with them.

Any molecule tends to sink vertically under the action of gravity, and its weight consequently develops a force or pressure in the direction of flow which may be considered as applied to it. All forces, then, necessary to overcome the resistances, are comprised in the molecule itself, and if its motion be uniform these resistances must be equal to the force developed in the direction of motion, whatever that direction be. As a logical sequence, in any river flowing with steady (not flood) motion, and having an irregular bed, the resistances in each section would be measured by the forces as above mentioned developed in that section, whatever the inclination of the bed. This is necessary in order that all molecules move instead of lying in stagnant pools, and is conceded in pipe flow. It will also be seen that pressure is required to produce this effect.

The writer's mode of expression on page 1005* was unfortunate.

* *Proceedings*, Am. Soc. C. E., for November, 1901.

Mr. Tutton. It was not the intention to assert that atmospheric pressure, as distinct from gravity, produced motion, but to remove the hydraulic grade line, so that such grade line could be compared with that of a pipe, exterior to the liquid in the pipe.

To further justify the elliptical velocity curve, the experiments in Tables Nos. 3 and 4 are presented, in which, however, f does not equal ε. No effort has been made to find the most perfect fitting curve, but it is suggested that, developed on the laminar theory, they plainly show that the assumption of no resistance at the surface is not true, and that forces developed by weight are not necessarily weight itself.

TABLE No. 3.—Vertical Velocity Curves at Carrollton, Miss., 1883. W. G. Price.

See Chief of Engineer's Report, 1884, page 2878.

Depths, in tenths.	Average of 12 Verticals. Wind Down Stream.		Average of 16 Verticals. Wind Up Stream.		Average of 8 Verticals. Rising River.		Average of 53 Verticals. Mean of All.		Average of 21 Verticals Falling River.	
	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.
Surface.	5.34	5.33	5.72	5.65	5.96	5.99	5.49	5.44	2.72	2.67
0.1......	5.42	5.41	5.80	5.74	6.09	6.10	5.60	5.54	2.75	2.72
0.2......	5.44	5.46	5.79	5.80	6.14	6.16	5.60	5.60	2.75	2.75
0.3......	5.48	5.48	5.82	5.82	6.18	6.18	5.62	5.62	2.75	2.75
0.4......	5.48	5.46	5.75	5.80	6.13	6.16	5.60	5.60	2.68	2.72
0.5......	5.42	5.41	5.74	5.74	6.12	6.10	5.55	5.54	2.68	2.67
0.6......	5.36	5.33	5.76	5.65	6.03	5.99	5.53	5.44	2.59	2.59
0.7......	5.28	5.18	5.67	5.49	5.98	5.83	5.48	5.28	2.50	2.47
0.8......	5.10	4.98	5.48	5.16	5.79	5.60	5.24	5.05	2.44	2.30
0.9......	4.66	4.67	4.92	4.92	5.23	5.23	4.70	4.70	2.04	2.04
1.0......	3.05	3.81	3.05	3.97	3.64	4.22	3.07	3.72	1.35	1.34
n	....	0.30	....	0.30	....	0.30	....	0.30	....	0.25

D. F. Henry's experiments on the Niagara, St. Lawrence, and St. Clair, are also referred to.*

Mr. Herschel's remarks, however appropriate to pipes, are scarcely applicable to rivers where current meters must be used, Venturi meters and weirs not being applicable. E. C. Murphy, Assoc. M. Am. Soc. C. E., in his paper on "Current Meter and Weir Discharge Comparisons,"† shows that these two methods of measurement agree remarkably well; yet, when using a current meter, velocity curves must be considered. He would be a poor engineer who could not use his instru-

* *Journal*, Franklin Inst., 1871.

† *Proceedings*, Am. Soc. C. E., for September, 1901.

Mr. Tutton.

TABLE No. 4.—Ellis's Experiments on the Connecticut.

United States Chief of Engineers' Report, 1875 and 1878.

Depth.	Mean of Meter Observations, below Average Velocity of 1.86.		Same, for Float Observations.		Mean of all Observations, below Average Velocity of 1.86.		Mean of Meter Observations, above Average Velocity of 1.86.		Same, for Float Observations.		Mean of all Observations, above Mean Velocity of 1.86.		Mean of all Meter Observations.		Mean of all Float Observations.		Mean of all Observations.	
	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.	Observed.	Calculated.
0.0...	1.15	1.17	1.50	1.49	1.21	1.22	2.96	3.06	3.26	3.13	3.01	3.07	2.05	2.11	2.38	2.38	2.10	2.15
0.1...	1.19	1.20	1.52	1.51	1.25	1.25	3.08	3.10	3.24	3.17	3.11	3.11	2.12	2.14	2.38	2.37	2.17	2.18
0.2...	1.22	1.22	1.52	1.52	1.27	1.27	3.12	3.12	3.17	3.18	3.13	3.13	2.15	2.15	2.35	2.36	2.19	2.19
0.3...	1.22	1.22	1.53	1.51	1.27	1.27	3.06	3.10	3.17	3.17	3.08	3.11	2.13	2.14	2.35	2.31	2.17	2.18
0.4...	1.19	1.20	1.49	1.49	1.24	1.25	2.99	3.06	3.11	3.13	3.01	3.07	2.08	2.11	2.30	2.28	2.12	2.15
0.5...	1.14	1.17	1.46	1.45	1.19	1.22	2.91	2.98	3.01	3.06	2.93	3.00	2.01	2.05	2.23	2.22	2.05	2.09
0.6...	1.11	1.12	1.35	1.39	1.15	1.17	2.78	2.87	2.94	2.96	2.81	2.89	1.93	1.97	2.15	2.14	1.97	2.01
0.7...	1.03	1.05	1.29	1.31	1.07	1.09	2.62	2.71	2.80	2.83	2.65	2.73	1.81	1.86	2.04	2.04	1.85	1.90
0.8...	0.94	0.94	1.20	1.20	0.99	0.98	2.42	2.49	2.60	2.64	2.45	2.52	1.67	1.70	1.90	1.90	1.71	1.73
0.9...	0.79	0.79	0.97	0.98	0.82	0.82	2.16	2.16	2.35	2.35	2.20	2.20	1.47	1.47	1.66	1.71	1.50	1.50
1.0...	0.46	0.36	0.58	0.58	0.48	6.37	1.47	1.26	1.78	1.58	1.53	1.83	0.96	0.83	1.18	1.19	1.00	0.85
n	....	0.25	....	0.20	....	0.25	....	0.20	....	0.20	....	0.20	....	0.20	....	0.00	......	0.20

Mr. Tutton. ments, and it is considered that the meaning of these velocity curves lies as much in the province of the engineer as in that of the physicist. Sewers have been tested in Buffalo by using a mixture of fluorescein and sodium hydrate, but without results comparable to those of Mr. Benzenberg, and if his experiment be considered conclusive, Mr. Herschel's subsidiary currents would appear to be without foundation.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXVIII. No. 2.

FEBRUARY, 1902.

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1902.

American Society of Civil Engineers.

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

House of the Society—220 West Fifty-seventh Street, New York.

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Vol. XXVIII. FEBRUARY, 1902. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

FORTY-NINTH ANNUAL MEETING.*

January 15th, 1902.—The meeting was called to order at 10.25 A. M., President J. James R. Croes in the chair; Charles Warren Hunt, Secretary.

Messrs. John B. Duncklee and G. W. Bramwell were appointed tellers to canvass the ballots for officers for the ensuing year.

The reading of the minutes of the meeting of January 8th was dispensed with.

* A full report of the Forty-ninth Annual Meeting is printed on pages 34 to 69 of this number of *Proceedings*.

The Annual Report of the Board of Direction * and the Annual Reports of the Secretary and of the Treasurer for the year ending December 31st, 1901, were presented, and, on motion, duly seconded, accepted.

The consideration of the following proposed amendment was then taken up:

Amend Article III of the Constitution as follows:

"(a) By changing the numeration of the present paragraphs 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 & 11 respectively to 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, & 12.

"(b) By prefixing a new paragraph, ...1...., to read as follows, viz., '1.—Election to membership in every grade shall be by the Board of Direction and respectively as hereinafter provided.'

"(c) By striking out the concluding ten words in the present paragraph 3 newly numbered 4 and substituting in place thereof the following, * * * 'may then proceed to take action on the applications.'

"(d) By inserting in the first line of new paragraph 5, after the first occurrence of the word 'ballots,' the words 'for the election of Corporate Members.' Also by striking out the word 'Corporate' before Member, in the second line and inserting the words 'of the Board' after the same. Also by striking out the three concluding lines and substituting therefor, the following, viz, 'Three or more negative votes shall prevent the election of a candidate. In the case of election the Board shall at once notify the membership. In the case of failure to elect the candidate shall be notified. In either case, all the correspondence pertaining thereto shall be preserved by the Board.'

"(e) By striking out all of the present paragraph 5, newly numbered 6, and substituting therefor a new paragraph 6, as follows, viz., '6—In case of failure to elect a candidate a new application by the same candidate shall not be accepted or considered until after the expiration of one year from the date of the ballot at which his name was last presented for election.'"

This amendment was proposed by Messrs. Foster Crowell, B. M. Harrod, W. J. Hardee, Henry B. Richardson, John Findley Wallace, Charles L. Strobel and Ralph Modjeski, and was presented for discussion at the Thirty-third Annual Convention, at Niagara Falls, N. Y., June 25th, 1901. It was at that meeting referred to a Committee consisting of seven members, one from each Geographical District, for report to the Forty-ninth Annual Meeting.

The report of the Committee on the advisability of the Proposed Amendment to the Constitution relating to the manner of election of members† was presented by the Secretary.

The amendment was discussed, but was not amended.

* See pages 5 to 18 of *Proceedings* for January, 1902, for the Annual Reports of the Board of Direction, the Secretary and the Treasurer.

† See page 35.

The following resolution was offered by Theodore Cooper, M. Am. Soc. C. E.:

Resolved, That it is the sense of this meeting that the Board of Direction shall have the power to classify applicants before their names appear on any published list of candidates; and, further,

Resolved, That a committee be appointed to report an amendment to the Constitution, which shall embody this idea, and report it at the next Annual Convention, for consideration.

The resolution was adopted.

The following resolution was also offered by Mr. Cooper:

Resolved, That a committee be appointed to report to the next Annual Convention upon raising the standard of qualifications for the several grades of membership.

The resolution was adopted.

It was moved, seconded and carried that the questions embodied in the two foregoing resolutions be referred to the same committee and that that committee, which shall consist of one member from each of the seven geographical districts, be appointed by the President.

The Secretary presented a report of the Committee on Uniform Tests of Cement.*

It was moved by F. W. Skinner, M. Am. Soc. C. E., that the report be accepted, and thatthe recommended change in the title of the Committee be made.

The motion, being duly seconded, was carried.

The following were appointed members of the Nominating Committee for two years:

JOHN G. VAN HORNE.........	*Representing*	*District*	*No. 1.*
GEORGE A. KIMBALL.........	"	"	*No. 2.*
JOHN F. ALDEN.............	"	"	*No. 3.*
SAMUEL TOBIAS WAGNER.....	"	"	*No. 4.*
AMBROSE V. POWELL.........	"	"	*No. 5.*
JAMES M. JOHNSON..........	"	"	*No. 6.*
WILLIAM W. FOLLETT........	"	"	*No. 7.*

The Secretary read a telegram from E. L. Corthell, M. Am. Soc. C. E.†

The Secretary reported that the Board of Direction has awarded the prizes for the year ending with the month of July, 1901, as follows:

The Thomas Fitch Rowland Prize to Paper No. 881, entitled "The Ninety-sixth Street Power Station of the Metropolitan Street Railway Company, of New York City," by L. G. Montony, Assoc. M. Am. Soc. C. E.

The Collingwood Prize for Juniors to Paper No. 883, entitled "A Proposed Method for the Preservation of Timber," by F. A. Kummer, Jun. Am. Soc. C. E.

* See page 50.

† See page 63.

The Secretary reported the result of the ballot on the appointment of the proposed Special Committee on Rail Sections.*

The Secretary read a letter† from John F. Wallace, Past-President Am. Soc. C. E., calling attention to the proposed Isthmian Canal, and proposing that the meeting should formulate an expression of opinion to be directed to Congress.

On motion, duly seconded, it was voted to refer the matter to the Board of Direction, with power.

A motion to memorialize Congress and send a committee to Congress to present reasons why the civil engineering profession at large should be considered in the Bill for the prosecution of work on the proposed Isthmian Canal was offered, discussed, and laid upon the table.

The Secretary read a letter from Roberto Gayol, M. Am. Soc. C. E., inviting the Society to hold its Annual Convention of 1903 in the City of Mexico.

The Secretary presented the report‡ of the tellers appointed to canvass the Ballot for Officers for the ensuing year.

The President announced the election of the following officers:

President, to serve one year:

ROBERT MOORE, St. Louis, Mo.

Vice-Presidents, to serve two years:

CHARLES C. SCHNEIDER, New York City.
JOHN R. FREEMAN, Providence, R. I.

Treasurer, to serve one year:

JOSEPH M. KNAP, New York City.

Directors, to serve three years:

District No. 1.—RICHARD S. BUCK, New York City.
District No. 1.—GEORGE H. PEGRAM, New York City.
District No. 1.—WILLIAM J. WILGUS, New York City.
District No. 2.—WILLIAM JACKSON, Boston, Mass.
District No. 3.—EDMUND F. VAN HOESEN, Buffalo, N. Y.
District No. 7.—JAMES L. FRAZIER, San Francisco, Cal.

* See page 55.
† See page 55.
‡ See page 64.

A vote of thanks was passed for the tellers who canvassed the Ballot for Officers.

The following resolution, offered by J. A. Ockerson, M. Am. Soc. C. E., was duly seconded and carried:

"*Resolved*, That the American Society of Civil Engineers heartily favors the collection of a representative engineering exhibit for the Louisiana Purchase Exposition, to be held in St. Louis in 1903, to illustrate in a creditable way the important part that the engineering profession has taken in the material progress of the country during the past century, and to this end we recommend the earnest co-operation of all members of this and other engineering societies."

The Secretary made announcement of certain features in connection with the programme of the Annual Meeting, and read a letter from George H. Pegram, M. Am. Soc. C. E., inviting the Society to inspect the power-house of the Manhattan Railway Company, at Seventy-fourth Street and East River.

The President called Vice-President C. C. Schneider to the chair.

Adjourned.

February 5th, 1902.—The meeting was called to order at 8.45 P. M. Emil Kuichling, Director, in the chair; Charles Warren Hunt, Secretary; and present, also, 96 members and 13 guests.

The minutes of the meeting of January 8th, 1902, were approved as printed in the *Proceedings* for January, 1902. The approval of minutes of the Annual Meeting was deferred until they are printed in the *Proceedings* for February, 1902.

A paper entitled "The Supporting Power of Piles," by Ernest P. Goodrich, Jun. Am. Soc. C. E., was presented by the author.

The Secretary read a communication on the subject by E. Sherman Gould, M. Am. Soc. C. E., and the subject was discussed verbally by H. J. Howe, M. Am. Soc. C. E., and the author.

Ballots were canvassed and the following candidates declared elected:

As Members.

Charles Francis Chase, New Britain, Conn.
Andrew Oswald Cunningham, Cleveland, Ohio.
Wilhelm Hildenbrand, New York City.
John Wykeham Jacomb-Hood, London, England.
William Pliny Snow, Auburndale, Mass.
John Marshall Gilkison Watt, Frankfort, Ky.
Julius Christian Wiest, Managua, Nicaragua.

As Associate Members.

Thomas Pettus Branch, Atlanta, Ga.
James Burden, Troy, N. Y.
Frederick Edwards, Schenectady, N. Y.
George Alec Harwood, New York City.
Frederic de Peyster Hone, New York City.
Thomas Forrester McGilvray, Duluth, Minn.
Alexander Orr, Gloversville, N. Y.
Edward Dana Sabine, Wakefield, Mass.
William Ambrose Dudley Short, Lexington, Ky.
Charles Joseph Tilden, New York City.
Robert Spurr Weston, Boston, Mass.
Percy Hartshorne Wilson, Camden, N. J.

The Secretary announced the election of the following candidates by the Board of Direction on February 4th, 1902:

As Associates.

William Rogers Copeland, Philadelphia, Pa.
Almon Homer Fuller, Seattle, Wash.

As Juniors.

Clifford George Dunnells, Pittsburg, Pa.
Myron Samuel Falk, New York City.
Stanley Alfred Miller, Mobile, Ala.
Luis Gonzaga Morphy, Troy, N. Y.
Walther Raster, Chicago, Ill.
Clarence Webster Raynor, Detroit, Mich.

The Secretary announced the death of the following Members:

Moritz Lassig, elected Member April 2d, 1884; died January 13th, 1902.

Nathaniel Edwards Russell, elected Member October 3d, 1888; died January 14th, 1902.

William Van Slooten, elected Member November 3d, 1897; died December 14th, 1901.

Adjourned.

February 19th, 1902.—The meeting was called to order at 8.45 p. m., Nelson P. Lewis, M. Am. Soc. C. E., in the chair; Charles Warren Hunt, Secretary; and present, also, 81 members and 14 guests.

A paper by Walter Loring Webb, Assoc. M. Am. Soc. C. E., entitled "Some Devices for Increasing the Accuracy or Rapidity of Surveying Operations," was presented by title.

Written discussions by Messrs. G. H. Matthes, C. A. Sundstrom, John F. Hayford, Willard D. Lockwood and L. C. Sabin were presented by the Secretary. The subject was discussed verbally by Messrs. Oscar Erlandsen, R. B. Stanton and George A. Taber.

The Secretary announced the death of KENNETH OAKE PLUMMER REINHOLDT elected Junior, February 6th, 1894; Associate Member, October 7th, 1896; died February 6th, 1902.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

January 15th, 1902.—2 P. M.—Vice-President Haines in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Buck, Croes, Freeman, Knap, Kuichling, O'Rourke, Pegram, Schneider, Seaman and Wilgus.

A Finance Committee, a Library Committee, a Committee on Publications, and a Committee on Membership were appointed.

A letter-ballot of the Board was ordered for the election of a Secretary for the ensuing year.

Adjourned.

February 4th, 1902.—8.05 P. M.—Vice-President Schneider in the Chair; Charles Warren Hunt, Secretary, and present, also, Messrs. Briggs, Buck, Croes, Knap, Kuichling, Pegram, Seaman, Swain and Wilgus.

A letter-ballot for the election of a Secretary was canvassed by tellers appointed for the purpose, and Charles Warren Hunt was declared elected.

The resignations of Edmund C. Stout, Assoc. M. Am. Soc. C. E., and Arthur W. Robinson, Jun. Am. Soc. C. E., were accepted.

Progress Reports were received from the various Committees.

Action was taken in regard to members in arrears for dues.

Applications were considered and other routine business transacted.

Two candidates for Associate and six for Junior were elected.*

Adjourned.

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* See page 31.

REPORT IN FULL OF THE FORTY-NINTH ANNUAL MEETING, JANUARY 15th and 16th, 1902.

Meeting Called to Order.

Wednesday, January 15th, 1902.—The meeting was called to order at 10.25 A. M.; President J. James R. Croes in the chair; Charles Warren Hunt, Secretary.

The PRESIDENT.—This is the Annual Meeting, and is not one of the meetings in the regular course. The minutes of the meeting of January 8th, 1902, will be printed in the January *Proceedings*, and come up in due course for action at the meeting of February 5th. In view of this fact, the reading of the minutes of this last meeting may be dispensed with at this meeting, and so we will proceed with the regular business.

Tellers Appointed.

The first thing is the appointment of tellers to canvass the ballots for officers, which ballot will be closed at 12 o'clock, in accordance with the terms of the Constitution. Any members present who have not voted will have an opportunity to vote before that time. At 12 o'clock the ballot will be closed, and I appoint as tellers to canvass the votes Messrs. John B. Duncklee and George W. Bramwell. The tellers can proceed at once with the counting of the ballots that have been received, and any ballots that are received before 12 o'clock will be furnished to them before that time.

Report of the Board of Direction.

The first business in order is the report of the Board of Direction for the year 1901.

The Secretary read the report of the Board of Direction.*

The PRESIDENT.—The report of Board is received and will be placed on file. The next in order is the report of the Secretary.

The Secretary read his report.†

The PRESIDENT.—The report will be placed on file. The next in order is the report of the Treasurer.

The Treasurer read his report.‡

JOSEPH M. KNAP, Treasurer, Am. Soc. C. E.—Gentlemen, I simply wish to emphasize here to the members that, while we are paying off $5 000 on the bond and mortgage, the Board has considered that that is enough to pay, although we have made more money than that, considerably, during the past year, and it is good policy, the Board thinks, to let the present generation, so to speak, have the advantage of our profits and our prosperity, and not pay off everything. We might pay off this house debt in a very few years, but I think we can leave that to posterity. What has posterity done for us?

The PRESIDENT.—The Treasurer's report will be placed on file. The next business is the proposed amendment to the Constitution.

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* See *Proceedings*, Vol. xxviii, p. 5 (January, 1902).

† See *Proceedings*, Vol. xxviii, p. 15 (January, 1902).

‡ See *Proceedings*, Vol. xxviii, p. 18 (January, 1902).

Proposed Amendment to the Constitution.

The Secretary read the proposed amendment, as follows:

"Amend Article III of the Constitution as follows:

"(*a*) By changing the numeration of the present paragraphs 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11, respectively to 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 & 12.

"(*b*) By prefixing a new paragraph, ...1...., to read as follows, viz, '1.—Election to membership in every grade shall be by the Board of Direction and respectively as hereinafter provided.'

"(*c*) By striking out the concluding ten words in the present paragraph 3 newly numbered 4 and substituting in place thereof the following, * * * 'may then proceed to take action on the applications.'

'(*d*) By inserting in the first line of new paragraph 5, after the first occurrence of the word 'ballots,' the words 'for the election of Corporate Members.' Also by striking out the word 'Corporate' before Member, in the second line and inserting the words 'of the Board' after the same. Also by striking out the three concluding lines and substituting therefor, the following, viz 'Three or more negative votes shall prevent an election of a candidate. In the case of election the Board shall at once notify the membership. In the case of failure to elect the candidate shall be notified. In either case, all the correspondence pertaining thereto shall be preserved by the Board.'

"(*e*) By striking out all of the present paragraph 5, newly numbered 6, and substituting therefor a new paragraph 6, as follows, viz, '6.—In case of failure to elect a candidate, a new application by the same candidate shall not be accepted or considered until after the expiration of one year from the date of the ballot at which his name was last presented for election.'"

The SECRETARY.—I have the report of the Committee which was appointed upon the proposed amendment, which the chairman, Mr. G. S. Greene, Jr., has forwarded to me, and which he has asked me to present to the meeting.

The PRESIDENT.—The report of the Committee appointed at the Annual Convention to consider this proposed amendment to the Constitution will be read:

The report was read by the Secretary as follows:

Report of the Committee on the Advisability of the Proposed Amendment to the Constitution relating to the Manner of Election of Members.

The undersigned, having been appointed by the President of the Society, acting under the instructions of the Business Meeting held at the Annual Convention, June 25th, 1901, as a Committee to report to the Annual Meeting, January 15th, 1902, on "The Advisability of the Proposed Amendment to the Constitution relating to the Manner of Election of Members," having duly considered the matter, beg leave to report as follows:

The object of the amendment is to put the election of members in the hands of the Board of Direction, and that the other mem-

Discussion on Amendment to Constitution.

bers of the Society shall have no vote or power in the selection of members.

The reason for that change in the Constitution appears to be that several persons, after having been passed as proper candidates by the Board of Direction, have been rejected by the vote of the corporate members of the Society, and that, having asked for reconsideration and another vote, a number of them have been admitted to the Society.

Upon looking up the records of the Society, it appears that, in the past ten years, thirty-two candidates have been rejected by vote of the members of the Society and have asked for reconsideration and been voted upon by what is generally known as the "pink ballot." Of these thirty-two, nineteen were elected members of the Society and the other thirteen were defeated.

It does not seem to your committee that the small number—averaging three a year—of these rejections and reconsiderations is of sufficient consequence to make a change in the Constitution involving the disfranchisement of the members. It is, of course, not impossible for the Board of Direction to make an error, and it is possible that in case they should do so it may possibly be corrected by the ballot of the members.

It appears that one cause of the rejection of candidates by the ballot is that of their classification; at present the Board of Direction classifies a man according to his request. If he were classified by the Board of Direction according to its judgment, it seems probable that the number of rejections would be greatly diminished.

Your Committee therefore begs leave to report against the advisability of the proposed amendment, and to recommend that measures be taken to give the Board of Direction power to classify the candidates before sending them to ballot.

G. S. Greene, Jr.	District	No. 1
Edmund K. Turner....	"	No. 2
John Kennedy................	"	No. 3
John T. Fanning..............	"	No. 5
Benjamin L. Crosby..........	"	No. 6
Geo. H. Mendell............	"	No. 7

The Secretary.—This report is signed by every member of the Committee except the representative of District No. 4, Mr. Bernard R. Green, who is here.

Foster Crowell, M. Am. Soc. C. E.—I would like to ask the Secretary whether the Committee formulates any amendment to be substituted for the one proposed and to be presented to the Society for ballot?

The Secretary.—It has not. I will say that the Chairman of the Committee has spoken to the Secretary about that, but he did not think, as I understood him, that it was possible to make an amendment to the original motion at this time which would be germane to it, under the Constitution. The Constitution says that a proposed amendment may be amended in a manner pertinent to the original resolution. The object of this proposed amendment is to place the

election of all members in the hands of the Board of Direction and take it out of the hands of the Society.

THEODORE COOPER, M. Am. Soc. C. E.—Do I understand that the Board of Direction has no right to classify candidates? Has not the Board a right, if the evidence is before it that a man should belong to a particular class, to put him there and not nominate him, as he asks to be nominated? If a candidate asks admission to this Society as a member, is the Board compelled to recommend him as a member, although it may find him thoroughly competent for a junior grade? I think it belongs to the Board of Direction to decide that, and it seems to me that, where there is any doubt, the Board can better give a junior grade, because the man has his remedy the following year. It does not seem to me that we need any amendment to the Constitution to correct that error. It seems to me that the Board can say, this man is qualified for such and such a grade, and recommend him for that. It seems to me it is a question of judgment for the Board. The Board asks the members to give it opinions in regard to candidates, and that would seem to indicate that the Board has the authority to determine from the evidence presented to it whether a man is competent for this grade or that. It is a matter of judgment for the Board.

Mr. CROWELL.—I was just about to ask to have that section read which covers the authority of the Board in that case.

P. C. RICKETTS, M. Am. Soc. C. E.—Isn't it a very simple matter? That is, all the Board of Direction has to state to the man is this—and it has done it, I think, in times past: We will recommend your passing to ballot if you will accept a lower grade, and if you do not accept the lower grade we will not pass you to ballot, because we do not think you fit to pass to ballot on that grade. That has been done, and it certainly seems to me it can be done again. It seems to me that that covers the case.

The SECRETARY.—I think the evident misunderstanding as to the powers and practice of the Board in the matter of the classification of applicants can easily be cleared up.

The objections to the present system of self-classification by applicants for membership appear to be that every applicant, when considering his eligibility, may be assumed to have a very different point of view from that of many other members of the Society; this being evidenced by the negative votes which are cast on every ballot by members who are not personally acquainted with the applicant. The applicant's point of view as to eligibility may also be said to be very different from that of the Board of Direction.

Very often, the Secretary has to assume the responsibility of returning applications because they do not fulfill the letter of the constitutional requirements, and this has to be done without presenting the matter to the Board, and is usually caused by the applicant's special

Discussion on Amendment to Constitution (continued).

interpretation of the Constitution. When, however, the application fulfills the letter of the requirements of the Constitution for the grade applied for, the name, record and list of references of each candidate are published in the Blue List, and the applicant is thus advertised as a candidate for that particular grade. Under the present system, this also must be done before the application is brought to the attention of the Board of Direction.

The Board, after having secured at least five endorsements, considers the application together with all other information received concerning it, and either passes the applicant to ballot in the grade for which he applies, or notifies him that he is eligible for a lower grade, and that his name will be passed to ballot in that grade if he consents. It will be seen that the applicant who accepts the classification of the Board is thus placed in a somewhat uncomfortable position in having applied for a grade for which he is not eligible, and, after having been advertised as an applicant for that grade, appears on the ballot list as a candidate for a lower grade.

A member of the Society, when an engineering friend states that he wishes to join, and asks for his support, naturally promises, without making special inquiry as to the grade for which his friend intends to apply, that he will give it. When confronted with the blank form of endorsement adopted by the Board of Direction, he may find it somewhat difficult to answer the queries necessary to an endorsement, and may possibly be placed in the unpleasant position of being forced to recommend the applicant for a lower grade.

It is well known that generally every applicant desires the highest grade for which he thinks he is eligible, and that therefore many members scan the Ballot rather than the Blue List, and send in negative votes based on the briefed career which is printed, instead of furnishing the Board with their opinion as to his eligibility.

Besides this, there have been several exceptions to the general rule. There have been modest applicants, whom the Board would have been glad to class in a higher grade than that for which they applied, but did not have the power to do so.

The relief for this seems to be in arranging that each candidate, instead of fixing his own classification, should apply simply for admission to the Society; that his name, record and list of references should then be published in a Blue List similar to that now used, and containing a request that all members of the Society give the Board the benefit of their knowledge of the applicant. After having received the necessary number of endorsements, and all information possible concerning each candidate, the Board should then consider his application, and determine the grade to which he is eligible, and, after having secured his consent, should issue his name on the ballot list. Errors of classification would be much less likely to occur under this system than

under that now used, and the information concerning candidates as well as endorsements would be much more free, as it would enable each referee to state his opinion as to the proper classification of the gentleman whom he is endorsing, without being forced to endorse or to refuse to endorse for one particular grade.

The reading of the clause of the Constitution has been asked for.

(The Secretary read Article 3, Sections 2 and 3 of the Constitution.)

Mr. CROWELL.—I should like to ask the Secretary if, in his view, it would be possible, under the present Constitution, for the Board to consider the applications before they go out on the Blue List, as a practical matter, and pass upon that question then?

The SECRETARY.—It is possible that that might be done, but the Board has interpreted the Constitution to mean that the application did not come before it for consideration until it has gone out on the Blue List, and there have been some difficult cases, notably as between the grades of Associate Member and Associate. There are some gentlemen who are engaged in college work, for instance, and there has always been a question about their classification. Applications come in, and the Secretary has again and again taken them to the Membership Committee of the Board of Direction, and they have refused to pass upon them, on the ground that if this were done before the application came before the Board for final adjudication, the Board would have already committed itself to the fact that the applicant was eligible to a certain grade, before having received the answers from his endorsers. The Constitution will have to be amended if such an idea goes through, because it states distinctly that applications must be made for Member or Associate Member, Junior, and so on.

B. R. GREEN, M. Am. Soc. C. E.—On that particular point it seems to me that the Board needs the backing of an amendment to the Constitution. A candidate's name being sent out on the Blue List for the grade of Member, being returned to the Board and afterward classified for a lower grade, puts the candidate in a somewhat delicate position. He has already come before the Society as desiring the grade of Member. He thinks he is qualified for that class, and it is a delicate position for him, to be, in a way, turned down publicly. I think that if the Board had the opportunity, and was sustained by the Constitution, to first classify the candidate, with his consent, that that little difficulty would be overcome. It seems to me it is rather an important point.

Mr. COOPER.—Mr. President, it seems to me that this Society has reached that stage of prosperity and standing that we can afford to raise the bars. Let us make the bars higher so that the applicant has got to jump a little higher to get in. I think the whole subject of grading and the requirements for membership in this Society should be revised and made so that we can elevate still higher the standing

[illegible] the Society claims to hold and does hold. Personally, I think that every man that enters this Society should enter it in a grade below that of Member, and earn his promotion, and not get it through the recommendation of his friends, but enter as an Associate Member or a Junior, and earn his promotion, and come before us again for our ballot. This is rigid and strong, I acknowledge, but it tends to the benefit of our Society, if we take up that matter, and I will move you, sir, that a committee be appointed to consider this subject and present it to the consideration of the Society at its next Convention, or later.

The PRESIDENT.—Is that motion seconded?

H. S. HAINES, Vice-President, Am. Soc. C. E.—I will second the motion, sir, with a view of requesting the gentleman who has just made it to present the matter in his resolution a little more clearly. From what I have heard of the discussion in the meeting, it seems to be the sense of the members present that the general idea that the Board should classify the applicant as to the particular class of membership to which he should be elected or for which he is eligible, prevails in this meeting. I would therefore ask the gentleman if it would not be better, in presenting his resolution, that he should say, that as it is the sense of this meeting that it is desirable that the Board should classify applicants at the time they make their application for membership, that the committee which he proposes should be appointed should prepare an amendment to the Constitution conformable to the views which have prevailed in this meeting, and that they should present their report at the next Annual Convention.

Mr. COOPER.—I have no objection to accepting that amendment. I think, however, the vote of this meeting in favor of the resolution is the sense of the meeting, but I have no objection, sir.

The PRESIDENT.—The motion should be presented in writing, so that we can understand it thoroughly. If the gentleman will present it, it will be entertained. The sense of this meeting has not been obtained on any subject.

Mr. CROWELL.—While the Secretary is writing it, I will merely call attention to the matter of procedure. It has been suggested by the gentleman who seconded the motion that the committee should be directed to report at the Annual Convention. That would simply delay the action of the bringing of the amendment before this Society. If the resolution were to direct that the committee present the amendment in the form provided by the Constitution previous to the Convention, then it could be considered by the Convention as an amendment, the Constitution explicitly providing for the way in which all amendments shall be presented.

J. A. OCKERSON, M. Am. Soc. C. E.—I don't know but what this is as good a time as any to say that I have been instructed by the members of the Society in St. Louis to express their disapproval of placing

the election of members in the hands of the Board of Direction; and I was furthermore instructed to say that if the negative vote at the present time is not sufficiently large to control the membership, that it will be desirable to have that made on a percentage basis. I am simply now expressing the views of the St. Louis members at quite a largely attended meeting held a short time before I came here.

E. A. BOND, M. Am. Soc. C. E.—I am very glad to hear the remarks of the gentleman who has just spoken. I am a Republican. I believe in annexation. I am opposed to Imperialism. Hence I think that the election of members of the different grades, either Members or Associate Members, as the case may be, should be by ballot of the whole membership of this Society, and not be placed in the hands of the Board of Direction. I am content that the Board of Direction should decide the grades in which particular members should join, but I think their election should be by a vote of the members of this Society.

Mr. GREEN.—I rose a little while ago, when the report of the Committee on the amendment had been read, to give something of my reasons for declining to sign with my colleagues, and, from what I have heard on the subject, I am rather more disposed to say a word in self-defence. The election of members, as we all must admit, is practically in the hands of the Board now, and always has been. The Board has classified members; it has practically controlled. The issue of the Blue List is to collect all the information to be had about a candidate. It is their business to do so and it is the business of members to inform the Board. I did not like the word "disfranchisement" used in the report. I do not think it applies. The Board is a representative Board, entirely representative of the whole Society. It has been made so with the greatest care in the recent amendments to the Constitution, and the Board, acting for the Society in the election of members, can do it just as well as the members can, and a great deal better—and much more economically. What is a vote sent out by letter for? Simply to find out how many members are going to vote against the candidate. Those who are going to vote in favor do not need to have a ballot sent to them, for the Board has already canvassed the ballot and made up its mind, from all the information it has been able to gain, that the candidate is eligible for election. The Board acts in the capacity of a Committee on Eligibility and a Committee on Acceptability, as we have in certain other organizations, in order to determine, after getting together all the information, whether a candidate is suitable for membership or not. Why do men vote against the candidate? Generally, I think, for some personal reason, or they may desire the opportunity to vote against the candidate in order to gratify some personal feeling, or at least to have the opportunity of expressing their objection secretly. There are sometimes good reasons for that. Of course, you can under-

Discussion on Amendment to Constitution (continued).

stand that a member may feel that he must proceed secretly in his negative vote because it may concern some candidate who is socially or otherwise connected with the voter in a delicate way, which makes him hesitate to make known to anybody, even to a single individual, his objection to the candidate. He has plenty of opportunity. The number of cases must be extremely rare where he would not have all the necessary opportunity to present his objection to the Board, or to some member of the Board. He can find somebody, certainly, on the Board to whom, if he did not wish to trust the whole Board, he could present his objections, and we know that the Board never sends out a letter-ballot if any reasonable objection at all has come before it. If a candidate is rejected this year, he may be elected the next. All we want to look out for is that the candidate is not accidentally or mistakenly elected a member of the Society, for after he is once in he cannot be gotten rid of. I do not think that the Society would be disfranchised. Many clubs and societies having a larger membership than this one put the election of their members, for economy and for the best of reasons, into the hands of their Board of Management or some Committee on Admissions, or something of that kind, and avoid not only the labor, but the considerable expense, as occurs particularly in this Society, of the letter-ballot system. If we go to the extent of a pink ballot, there has to be printed and sent out to all members of the Society, first, a Blue List; then a printed vote; then a printed notice of a pink ballot, and finally the pink ballot. I think that the Secretary could give figures as to the expense of that procedure that would seem to make it desirable to save the expense and the time. The question has seemed to me an extremely simple one, as a matter of economy, and the sending out of the ballot to members is only for the purpose of finding out who there may be in the Society to vote against the candidate after the Board of Direction, a representative body of the Society, has, in the most painstaking way, gone over the whole subject to determine the eligibility and desirability of the candidate.

R. B. Stanton, M. Am. Soc. C. E.—I do not know what there is before the house that will allow what I wish to say in regard to this matter, but from Mr. Green's remark I want to express one thing. Undoubtedly, the best interests of this Society, in my opinion, would be served by electing the members by the Board of Direction, provided there was that one item of publicity to their action, at least to the members of the Board of Direction themselves, who were not able to be present at the meeting at which that action was taken.

I have a personal feeling in that regard, from an occurrence that happened when my dearest friend, who afterward became a member of this Society, was turned down by the Board of Direction and refused an opportunity to go to a ballot, simply upon the letters of two gentlemen some 3 000 miles away from New York, and only by acci-

dent, I being at that time a member of the Board of Direction, did I know of the action taken by that Board. When I did learn of it, I requested from the Secretary, as I believed my right, the information as to why this gentleman had been turned down. I was then residing in California, and represented the Seventh District in the Board. When I received that information I prepared a statement which I presented to the Board of Direction, giving the facts in the case, and practically, I am sorry to say, giving the lie to everything that had been stated in the letters that had been sent to the Board. In other words, the information sent was not truthful.

Now, the point is simply this; that that information was sent, just as Mr. Green says. Ballots against members are cast for personal reasons, and I believe that the Board of Direction is the proper body to elect a member, provided it will give, especially to its own members and also to those who have proposed the new candidate, the information on which he is turned down. I think it is a very important point in regard to the action of any body, not in any way impugning the motives of the Board of Direction at that time, because it was pure ignorance on its part.

The gentleman to whom I refer was afterward passed to ballot, and I suppose I haven't the right to say, but he was practically unanimously elected, and a nobler man never existed on the face of the earth,—John Hislop, who was my first assistant for so many years, and who has to his credit the building of the Yukon Railroad, and who was only recently killed in Chicago.

Mr. Green.—My friend, Mr. Stanton, has stated an argument, I think, on my side. I was a member of the Board at the same time, I think, to which he refers. I remember his letter, and I remember the effect it had. He was a distant member, unable to come to the Board meeting. This amendment requires that all members of the Board shall vote by letter-ballot and shall be informed of everything that the Board knows. That is, the resident members or the members of the Board who are able to get to the meetings know about the whole subject, and, therefore, the distant member should have as much information in the matter, before the vote is cast, as the local members of the Board. Consequently, there is something in that. The member residing at a distance, away out West, unable to get to the meetings of the Board, is the man that the members in his vicinity can communicate with if they choose. He is the representative of that district on the Board, and whether he ever comes to a meeting or not, he should know as much about what is going on in the Board, in the matter of elections at least, as the local members, because the amendment requires that the election of members shall be by letter-ballot, just as it is now arranged for the whole Society.

Mr. Stanton.—I recognize Mr. Green's explanation, and I would

Discussion on Amendment to Constitution (continued).

say that I am not familiar with that amendment which has been drawn up. If that is all, it does not go far enough. I was the one who proposed Mr. Hislop's name for membership in the Society, and if I had not been a member of the Board I would not have gotten that information. It seems to me that there should be such information given at least to the five members to whom he refers. If I had not been a member of the Board at that time I would not have known anything about it, nor ever have had an opportunity to have given the positive information I did on which a very honorable man was elected to the Society.

Mr. Green.—There is only one other remark to make on that, that I can think of, and that is the illustration given by Mr. Stanton of the capable member that came into the Society after once being rejected by the Board. He finally got into the Society, and the Society was very glad to have him. It is a safer mistake to make to put off an election to membership a year or so, than it is to elect a member who would not be a desirable member of the Society, by mistake, for, once in the Society, he stays.

W. L. Saunders, M. Am. Soc. C. E.—What is the question before the house?

The President.—A motion has been offered which will now be read, and the Chair will decide whether that motion is in order or not.

The Secretary (reading.)—*Resolved*, that the Report of the Committee be received and placed on file; and be it

Resolved, that it is the sense of this meeting that the Board of Direction shall have the power to classify applicants before their names appear on any published list of candidates, and further,

Resolved, that a Committee be appointed to report an amendment to the Constitution which shall embody this idea, and report it to the next Annual Convention for consideration, and that said Committee be also requested to report upon raising the standard of qualifications for the several grades of membership.

The President.—As an expression of the views of this meeting, I think that that resolution will be in order, but it has no effect whatever on the question which is now before the house. The question is on the amendment to the Constitution which was offered, and which has been before the Society. This amendment to the Constitution may be amended in any manner pertinent to the original amendment by a majority vote of the Annual Meeting, and, if so amended, shall be voted upon by letter-ballot in the form as amended by the Annual Meeting. If not so amended, it shall be voted upon by letter-ballot as submitted. If this meeting desires to formulate an amendment to this amendment to the Constitution which is now before the Society, and to adopt such an amendment, they can do so, and that amendment to the Constitution, as amended by this meeting, will go

to ballot. If not so amended, it must go to ballot in the form in which it was presented. An expression of opinion by this meeting has no binding force on anybody. It is merely an expression of opinion, and that is all that this resolution is. If the members present desire to express their opinion as to what the Constitution ought to be, they can do so, but if the amendment to the Constitution which was offered, and which is formally before the Society, is amended by this meeting, it must go to ballot. If it is not so amended, it must go to ballot. An expression of opinion by this meeting on the general subject has no force and cannot go out officially except just as an expression of opinion of this meeting.

Mr. Cooper.—I am to blame for the present situation of affairs. I withdraw that resolution temporarily, and now move that it is the sense of this meeting that the amendment to the Constitution be not recommended, which is the subject previously before the meeting, and I now move that the amendment be not adopted.

(The motion was seconded.)

Mr. Crowell.—Before that motion is put I would like to call attention to the fact that the amendment has been presented, as the Chairman has stated, in the regular way, and goes before the Society. An expression of opinion as to whether or not the members should vote for that amendment will be taken, by the membership at large, who are not here, for what it is worth. I do not think, as a matter of policy—and I say this entirely apart from the fact that I was one of the presenters of the amendment—I think, as a matter of policy, that an Annual Meeting should not attempt to control the decision of the members, when the Constitution provides for the decision being rendered as the result of the printed ballot which is sent out to them. An expression here is not significant. It merely means that the majority of the people present at this time are against the amendment. I do not think, myself, that it is worth while, in view of the report and of the discussion which has taken place since, to expect that the amendment will be adopted by the Society, but I think the Society should be allowed to express its own opinion individually in the letter-ballot. Some of the objections which have been raised to the amendment in the report of the Committee seem to me pertinent. Others do not. I do not think the report indicates a full consideration of the objections to the present method. Mr. Green has referred to some of them; but, while I do not propose to criticise the report at all, I do hope that the meeting will allow this amendment to proceed on its way without making an expression of opinion either for or against it.

Samuel Whinery, M. Am. Soc. C. E.—I would like to know whether the Chair decides as to whether this amendment offered is or is not pertinent to the proposed amendment? It seems to me that that is the first thing to get out of the way.

Discussion on Amendment to Constitution (continued).

The PRESIDENT.—The Chair will give an opinion on that point shortly. Mr. Bogart has the floor.

JOHN BOGART, M. Am. Soc. C. E.—I wish to ask for information as to one point. As I understand the resolution, I am sure it is exactly in accordance with the Constitution, that whether this Annual Meeting takes action one way or the other, whether it amends this proposed amendment or does not, the amendment must go to ballot either in its original form or as amended by this resolution. Now, I wish to add one more question: If this Annual Meeting takes any action, as, for instance, a motion of disapproval or approval of this amendment, would such an action as that go out upon the letter-ballot with the amendment to the Constitution?

Mr. COOPER.—It has been ruled heretofore that this was the only deliberative body of this Society that represents our whole Society. Before this matter goes to ballot—it has been discussed here *pro* and *con*, and I think every one of us has previously made up his mind regarding it—I think, therefore, it would be unjust, to our Society and to those members who cannot come here to this meeting, to fail to express our approval or disapproval. It has been considered here, and certainly it would be cowardice on our part if we failed to express the feeling and the conclusion of this body. I therefore call for the motion.

A. L. HYDE, M. Am. Soc. C. E.—It would seem to me that this matter has been placed in the hands of a committee for consideration, and, before proceeding with the matter, it will be well to do something with that report. I therefore move that that report be received and placed on file. That disposes of that. Then the matter can be called up in order.

The PRESIDENT.—The report has been received and placed on file in the regular order of business, sir.

Mr. GREEN.—That report is already received?

The PRESIDENT,—Yes, sir; I have just stated that fact. A motion was offered by Mr. Cooper which he will please either reduce to writing or state in words so that the stenographer can take it down.

Mr. COOPER.—I move that this Annual Meeting recommend the amendment, and that the recommendation of the Committee be not accepted by this Society.

The PRESIDENT.—Is that the recommendation of the Committee, or the amendment to the amendment to tho Constitution?

Mr. COOPER.—The amendment.

The PRESIDENT.—Will you please state it accurately, then, what you do mean to say, or put it down in writing?

Mr. COOPER.—Perhaps I am in error as to what the Committee did recommend. What I want to do is to keep the election of the mem-

bers as it now stands, in the hands of the members of the Society. That is what I want to do, and that is what I want this meeting to recommend to be done.

The President.—Well, will you state your resolution, then, sir, so that the stenographer can take it down? The resolution must be pertinent to the amendment to the Constitution in some way.

Mr. Cooper.—Will you have the amendment read, sir?

The Secretary.—The purport of it is to put the election of all corporate members of the Society, as well as others, in the hands of the Board of Direction.

Mr. Cooper.—That is what I understood, and I move that that recommendation be not accepted—that this meeting recommend that it be not accepted or voted upon.

Mr. Crowell.—We have heard some objections raised here in respect to imperialism. Why is the letter-ballot provided——

The President.—I beg your pardon. There is a motion now before the house. If you will make your remarks more germane to that motion only——

Mr. Crowell.—I am speaking to that question only. Is it not a question of imperialism by this meeting to attempt to decide a matter for the Society at large? I ask why do we have the letter-ballot? It is simply to give an opportunity for the absent member to express his wishes. It may be pertinent for this meeting to pass such a resolution as a parliamentary proposition, but I think it is impertinent for it to do so for the membership at large.

Mr. Cooper.—I move that it is the sense of this meeting that the amendment proposed should not be passed.

The President.—Is that motion seconded?

The motion being duly seconded, was put by the Chair and carried.

The President.—The question now before the house is: Shall the amendment to the Constitution be amended before being sent out to ballot? I may state, with regard to that, that the proceedings of this meeting will be published and sent to all the members before the ballot can be issued, and that the ballot is counted at the first regular meeting in March. The proceedings of this meeting will go out to the Society before that amendment is voted upon, but the amendment as presented or as amended by this meeting must be voted upon on the first Wednesday in March. Are there any amendments offered to the amendment to the Constitution to be appended to it or to be incorporated in it, rather, and sent out to ballot? Are there any amendments? Is there any further discussion of the question? The Chair not hearing that any discussion of the question is asked for, and no amendments to the amendment to the Constitution having been offered by this meeting, the amendment offered and presented at the

Discussion on Amendment to Constitution (continued).

Convention will be sent out to ballot in its form as presented, to be voted upon on the first Wednesday in March.

The next order of business—

Mr. Cooper.—I now call up the resolution which I withdrew.

The Secretary.—(Reading) *Resolved*, that it is the sense of this meeting that the Board of Direction shall have the power to classify applicants before their names appear on any published list of candidates; and, further,

Resolved, That a Committee be appointed to report an amendment to the Constitution, which shall embody this idea and report it to the next Annual Convention for consideration, and that said Committee be also requested to report upon raising the standard of qualifications for the several grades of membership.

C. G. Darrach, M. Am. Soc. C. E.—I second the resolutions.

Mr. Ockerson.—Would it not be well to divide that question? Some members might wish to vote in favor of all except the last clause.

Mr. Cooper.—That is perfectly proper. I move that it be divided into two resolutions.

The President.—The resolution, with the consent of the proposer of the resolution, will be divided into two resolutions. The first resolution is—

The Secretary.—(Reading) *Resolved*, that it is the sense of this meeting that the Board of Direction shall have the power to classify applicants before their names appear on any published list of candidates; and, further,

Resolved, that a Committee be appointed to report an amendment to the Constitution, which shall embody this idea, and report it at the next Annual Convention for consideration.

Mr. Crowell.—I have already raised the point that if this Committee reports to the Annual Convention, it does not bring the amendment before this Society. It may be desirable to spend another year on it, but if this motion prevails, that Committee will report at the Annual Convention, but the amendment cannot come before the Society until the next Annual Meeting, a year from now. If that is the object, why, well and good, but otherwise the motion should read instructing that Committee to present an amendment to the Society in season for its consideration at the Annual Convention.

Mr. Cooper.—That is not my intention, Mr. Chairman. My intention is to bring this matter before the Convention, that represents our Society, for discussion. I am not endeavoring to push anything through this Society without the fair consideration of the members, and action being taken after a fair consideration. The first meeting that follows this, which fully represents the whole Society, is the Annual Convention. It is not a matter of such hurry as to go through

in one year, or whether it takes two years or five years, but I think it is a matter that the members should take up and consider—whether we are not now in such a state of prosperity and standing that we can afford to elevate the standard of our membership.

The PRESIDENT.—If there is no objection to the presentation of this resolution at this time—it may be that it will be rendered nugatory by the action of the Society on the first Wednesday in March—but that has nothing to do with it. The question now is upon the adoption of this resolution offered by Mr. Cooper.

The resolution being put to vote was unanimously carried.

The SECRETARY.—The second part of that motion, with the change that will be necessary, is:

Resolved, That a Committee be appointed to report to the next Annual Convention upon raising the standard of qualifications for the several grades of membership.

Mr. HAINES.—I second the motion, and if the meeting will permit me to occupy its time for a moment or two, I wish to say that I hope that this measure will prevail. Never mind whether it should be thought advisable that there should be any change in the standards of qualifications for membership in this Society, but the passage of this resolution will give that Committee an opportunity to consider this whole matter, and, as Mr. Cooper very properly said, to have it brought up for discussion at the next meeting at which the membership is fully represented. I do hope, therefore, that whatever may be your personal views, gentlemen, as to the advisability of making a change in the qualifications, that you will sustain this resolution to have this matter left to the Committee to report upon at the next Convention.

The PRESIDENT.—Gentlemen, it is now five minutes to twelve; the ballot will close at 12. Any members who have not voted for officers of the Society will have an opportunity to do so during the next five minutes, and no later, because the ballot will close at 12 o'clock.

The question is now on the adoption of Mr. Cooper's resolution.

The motion being put was carried.

The SECRETARY.—I would like to call attention to the fact that there is no provision in either of those resolutions as to how those committees shall be appointed or of how many members they shall consist, and I think it will be well for this meeting to fix that.

The PRESIDENT.—Will Mr. Cooper make the suggestion?

Mr. COOPER.—I think such matters are usually done by the Board of Direction, or by the Chair, are they not?

The SECRETARY.—The President had better do that, because the Board does not meet very often.

Mr. COOPER.—I would suggest that they be appointed by the Chair, sir.

The PRESIDENT.—And how many?

Mr. OCKERSON.—As far as I am concerned I think it would be preferable to follow the custom to appoint one from each district, on important matters of that kind.

The PRESIDENT.—Will you make a motion that they be appointed one from each of the districts, on each of these Committees?

Mr. OCKERSON.—I will.

The motion was duly seconded.

Mr. CROWELL.—Could not both those questions be referred to the same Committee, under the resolutions?

The PRESIDENT.—Well, there are two separate resolutions now.

Mr. COOPER.—It is, of course, in the power of the Chairman to appoint the same Committee.

Mr. HAINES.—I move that they be referred to the same Committee.

The motion, being duly seconded, was put to vote and carried.

The PRESIDENT.—It is now 12 o'clock, and the ballot is closed. The next thing in order is the report of the Cement Committee.

The SECRETARY.—I have been requested to present the following report:

JANUARY 15TH, 1902.

Committee on Tests of Cement.

TO THE PRESIDENT AND MEMBERS,
AMERICAN SOCIETY OF CIVIL ENGINEERS.

GENTLEMEN: The Committee on the Proper Manipulation of Tests of Cement desires to present the following report:

By authority granted at the last Annual Meeting of the Society the membership of the Committee has been increased to nine, by the addition of Messrs. S. B. Newberry, Clifford Richardson, Richard L. Humphrey and F. H. Lewis.

Three meetings of the Committee have been held, at which the work has been mapped out, and it is now well under way.

The Committee has considered and decided a number of details in connection with its final report. Much time has been devoted to a consideration of the advisability of substituting a natural sand for the standard quartz; and a series of tests has been undertaken with a view of determining the adaptability of the various natural sands for this purpose. The questions: Accelerated tests for constancy of volume, sieves and method of sieving, and normal consistency, have also been fully discussed.

At the last meeting of the Committee, in Philadelphia, its Secretary was instructed to prepare a preliminary report, embodying the reports of its members on the special subjects, to serve as a basis for the preparation of its final report.

It is the intention of the Committee to present a report at the next Annual Meeting of the Society, though some points must necessarily be left open even at that time.

The Committee was created by the Society to report on the proper manipulation of tests of cement. This limitation of its powers has proved a serious handicap. The Committee feels that it should be unrestricted and should have full power to act on all matters pertaining to its work. It desires to report, in connection with its recommendations, the data on which these recommendations were based. This it would be unable to do under its present powers.

The Committee would, therefore, submit for your consideration the desirability of increasing its powers, and would recommend that the title under which the Committee was created be changed to "The Committee on Uniform Tests of Cement."

For the Committee,

G. S. WEBSTER,
Acting Chairman.
RICHARD L. HUMPHREY,
Secretary.

F. W. SKINNER, M. Am. Soc. C. E.—I move that the report be accepted, and that the recommended change of title be also made.

The motion, being duly seconded, was put to vote and carried.

The PRESIDENT.—The next in order is the election of the Nominating Committee.

The SECRETARY.—Mr. President, the usual circular was mailed some time ago asking each member of the Society to indicate his choice of a member to represent his section on the Nominating Committee, and the following is the result: Nominating Committee.

District No. 1.—Total number of votes received, 60; distributed as follows:

JOHN G. VAN HORNE	9
GEORGE W. TILLSON	4
RICHARD S. BUCK*	3
EDWARD P. NORTH	3
H. W. BRINCKERHOFF	2
GEORGE W. CATT	2
ALLEN HAZEN	2
GEORGE A. JUST	2
CHARLES MACDONALD	2
CHARLES H. MYERS	2
GEORGE S. RICE	2

The following received one vote each:

JOSIAH A. BRIGGS,*
ALFRED P. BOLLER,
WILLIAM HENRY BALDWIN,
JOHN C. BRACKENRIDGE,
ALBERT CARR,
THEODORE COOPER,
HOWARD J. COLE,
JOHN VIPOND DAVIES,
JOSEPH P. DAVIS,
S. L. F. DEYO,
GEORGE W. FULLER,
PHILIP W. HENRY,
RUDOLPH HERING,
JOSEPH MAYER,
HENRY P. MORRISON,
GEORGE S. MORISON,
GEORGE W. MCNULTY,
O. F. NICHOLS,
JOHN F. O'ROURKE,*
H. B. SEAMAN,*
IRA A. SHALER*
J. WALDO SMITH,
EDGAR B. VAN WINKLE,
ROBERT VAN BUREN,
CHARLES DOD WARD,
F. STUART WILLIAMSON,
S. C. WEISKOPF.

The SECRETARY.—It has been the custom to take up these matters by districts in order to deal with them as we go through. There is a report for each district.

* Ineligible.

Nominating Committee (continued).

The PRESIDENT.—You have heard the vote which has been cast for a member of the Nominating Committee for the First District.

Mr. CROWELL.—I move the gentleman named having the highest number of votes, John G. Van Horne, be the representative of the First District.

The motion, being duly seconded, was put to a vote and carried.

District No. 2.—Total number of votes received, 37; distributed as follows:

JOHN P. SNOW	7
GEORGE A. KIMBALL	7
F. P. STEARNS	3
J. R. WORCESTER	3
A. S. CHEEVER	2
E. P. DAWLEY	2
GEORGE B. FRANCIS	2

The following received one vote each:

C. FRANK ALLEN, H. BISSELL, JOSEPH P. COTTON, JOHN W. ELLIS, JOHN R. FREEMAN,*, RICHARD A. HALE, HENRY MANLEY, JAMES W. ROLLINS, Jr., J. HERBERT SHEDD, GEORGE F. SWAIN,*, GARDNER S. WILLIAMS.

A MEMBER.—I move that George A. Kimball be appointed.

The motion, being duly seconded, was put to vote and carried.

District No. 3.—Total number of votes received, 22; distributed as follows:

JOHN F. ALDEN	4
ELNATHAN SWEET	2
WILLIAM A. HAVEN	2
LOUIS H. KNAPP	2

The following received one vote each:

GEORGE B. BASSETT, ROBERT CARTWRIGHT, EDWARD B. GUTHRIE, EDMUND HAYES, WILLIAM T. JENNINGS, W. B. LANDRETH, P. ALEXANDER PETERSON, CHARLES M. MORSE, JOHN C. QUINTUS, THOMAS W. SYMONS, CHARLES H. TUTTON, E. F. VAN HOESEN.*

Mr. RICKETTS.—I move that Mr. John F. Alden be nominated.

The motion, being duly seconded, was put to vote and carried.

District No. 4.—Total number of votes received, 62; distributed as follows:

SAMUEL TOBIAS WAGNER	15
JAMES L. LUSK	7
GEORGE S. WEBSTER	6
RICHARD KHUEN, Jr	4
GEORGE S. DAVISON	3
CHARLES B. BALL	2
H. M. WILSON	2
W. G. WILKINS	2

* Ineligible.

The following received one vote each:

John A. Atwood,	William T. Manning,
J. C. Bland,	Mansfield Merriman,
Charles Davis,	William Arthur Pratt,
Arthur P. Davis,	S. M. Prevost,
J. E. Greiner,	Thomas Rodd,
C. W. Haines,	L. Y. Schermerhorn,
Lewis M. Haupt,	E. G. Spilsbury,
John W. Hill,	Emil Swensson,
C. B. Hunt,	Edward B. Taylor,
Washington Jones,	Theodore Voorhees,
Paul L. Wölfel.	

G. S. Webster, M. Am. Soc. C. E.—I move that Samuel Tobias Wagner, having the largest number of votes, be elected a member from that district.

The motion, being duly seconded, was put to vote and carried.

District No 5.—Total number of votes received, 68; distributed as follows:

Ambrose V. Powell	11
Clifford Buxton	4
Onward Bates	4
Charles E. Greene	4
Augustus Mordecai	3
E. C. Carter*	2
C. W. Kittredge	2
Alfred Noble	2
H. E. Riggs	2
Job Tuthill	2
Samuel T. Wellman	2
George Y. Wisner	2

The following received one vote each:

George H. Benzenberg,*	M. W. Kingsley,
W. H. Bixby,	Thomas H. Johnson,*
James H. Brace,	G. A. Marr,
Daniel Bontecou,	Frank C. Osborn*,
L. F. G. Bouscaren,	H. W. Parkhurst,
D. D. Carothers,	W. D. Pence,
L. E. Cooley,	George S. Pierson.
James Dun,	Walter P. Rice,
John T. Fanning,	James Ritchie,
S. M. Felton,	William H. Searles,
Edward Flad,	W. A. Thompson,
Julian Griggs,	Eben S. Wheeler,
E. A. Handy.	L. L. Wheeler,
William H. Hughes,	August Ziesing.

R. W. Hunt, M. Am. Soc. C. E.—As from the district, I move that Mr. Ambrose V. Powell be selected.

The motion, being duly seconded, was put to vote and carried.

* Ineligible.

[illegible] *District No. 6.*—Total number of votes received, 51; distributed as follows:

James M. Johnson	....	11
[illegible] Rainsdell	....	7
[illegible] Perrilliat	....	5
[illegible] McDonald	....	3
[illegible] Hider	....	2
[illegible] M. Scott	....	2

The following received one vote each:

James P. Allen,	J. L. Ludlow,
J. R. Atkinson,	Louis R. McLain,
W. M. Black,	F. A. Molitor,
William W. Carson,	R. Montfort,
E. J. Chibas,	Henry B. Richardson,
Charles I. Churchill,	Miller A. Smith,
William P. Craighill,	B. F. Thomas,
Benjamin L. Crosby,	A. J. Tullock,
George G. Earle,	J. A. L. Waddell,
J. F. Hinckley,	R. L. Van Sant,

Any Member.

C. B. Stewart, Assoc. M. Am. Soc. C. E.—I move that Mr. James M. Johnson be elected as the member.

The motion, being duly seconded, was put to vote and carried.

District No. 7.—Total number of votes received, 25; distributed as follows:

W. W. Follett	....	2
C. D. Marx	....	2
A. Riffle	....	2

The following received one vote each:

A. L. Adams,	John D. Isaacs,
Eugene Carroll,	Lorenzo M. Johnson,
E. B. Cushing,	Lewis Kingman,
C. E. L. B. Davis,	W. H. Leffingwell,
W. A. Drake,	Franklin Riffle,
James L. Frazier,*	Andrew Rosewater,
C. E. Grunsky.	D. W. Ross,
J. Herron,	James D. Schuyler,
J. M. Howe,	E. Stenger,

E. T. Wright.

Mr. Crowell.—I move that Mr. William W. Follett be appointed.

The motion being duly seconded was put to vote and carried.

The Secretary.—The Secretary has received the following cablegram:

Cablegram from E. L. Corthell.

"Buenos Ayres, January 14th, 1902.

"Charles Warren Hunt,

"220 West 57th Street, New York City.

"My kindest regards and best wishes to all my friends for a pleasant re-union.

"E. L. Corthell."

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* Ineligible.

The PRESIDENT.—There is no action to be taken on that; the best wishes are reciprocated, undoubtedly.

The SECRETARY.—I have to report the following action by the Board of Direction.

Award of Prizes.

In accordance with the rules adopted for the purpose, the Board of Direction has made the following awards of prizes for the year ending with the month of July, 1901.

The Thomas Fitch Rowland Prize to Paper No. 881, entitled "The Ninety-sixth Street Power Station of the Metropolitan Street Railway Company, of New York City," by L. G. Montony, Assoc. M. Am. Soc. C. E.

The Collingwood Prize for Juniors to Paper No. 883, entitled "A Proposed Method for the Preservation of Timber," by F. A. Kummer, Jun. Am. Soc. C. E.

The Board has further decided that no award of the Norman Medal be made for the year ending with the month of July, 1901.

As that is merely a report, no action is necessary.

Ballot on Committee on Rail Sections.

I also have to report that the ballot on the appointment of the Special Committee on Rail Sections resulted as follows:

Total ballots received		1 098
Without signature	14	
Not entitled to vote	10	
Otherwise defective	18	
	—	42
Total votes counted		1 056
Voted yes		1 014
" No		42
		1 056

Inasmuch as the Corporate Membership on January 7th, 1902, was 2 122, the vote complies with the Constitutional provision, and the Committee will be appointed by the Board.

The following letter has been received from John F. Wallace, Past-President of the Society:

Employment of Engineers on Isthmian Canal.

CHICAGO, January 10th, 1902.

MR. CHARLES WARREN HUNT,
Sec'y., American Society of Civil Engineers,
220 West Fifty-seventh Street, New York.

MY DEAR SIR,—I understand the House bill for the construction of the Nicaragua Canal practically provides that this work shall be carried on under the supervision of the Secretary of War. This, of course, means under the direction of the Army Engineers.

It would seem that the large body of civil engineers in the United States should have proper representation on the staff selected to design and construct what will probably prove to be the most important engineering project of the 20th century.

Employment of Engineers on Isthmian Canal (continued).

It would seem proper that the American Society of Civil Engineers should take some action at its Annual Meeting to see that this important matter receives careful and proper consideration.

First, as to the wisdom of action in this direction; second, as to the method to be used to secure the results.

Personally, I am in favor of action by the Society at its coming Annual Meeting. Such action, it seems to me, should consist in the presentation of a formal resolution or memorial to both Houses of Congress. Whatever action is taken, if any, should be at the Annual Meeting.

If I am unable to attend the Annual Meeting personally, you are at liberty to present this letter to the Society.

Very truly yours,

John F. Wallace.

The President.—It is proposed by Mr. Wallace that this meeting should formulate an expression of opinion to be directed to Congress.

James Owen, M. Am. Soc. C. E.—I move that it be referred to the Board of Direction, with power.

Mr. Crowell.—I second the motion.

The President.—It is moved and seconded that the plan of presentation to Congress of a memorial be referred to the Board of Direction, with power.

Mr. Haines.—Will you pardon me if I say a few words on this subject. Of course, I am not personally interested in this work, but it does seem to me that if this Society has ever had a subject before it in which the professional interests of its members were more deeply involved, it has not been in the number of years that I have been a member, and I do hope that those who are more directly interested in it than I am will not permit this matter to go off in this perfunctory way.

I quite agree with every word that our Past-President has said, that there should be some effort made to have the profession of civil engineering properly represented in the construction of this great engineering work, and I do not see how the body of civil engineers as a whole can more thoroughly have its influence felt in the deliberations on this matter in Congress than through this, the properly constituted organ, for them to give expression to their opinions and their wishes; and I do hope that it will be brought up in such a way that if it is determined that it shall be presented to Congress that it shall be done officially, and that the Board, if it is left to them, should have power to act and power to pay for the expenses of a committee to present this thing properly before Congress. I know from past experience in other matters that it is much more efficient to have a committee personally present than to undertake to impress your views upon the minds of members of Congress through a printed memorial.

The President.—The question is referred by this resolution to the

Board of Direction, and the Vice-President will have an opportunity to express his views there.

Mr. HAINES.—Pardon me; I am not speaking as an official; I am speaking as a member of the great profession of civil engineers, not personally interested in this matter at all; but this, as I understand it, goes to the Board without any expression of opinion on the part of this meeting.

The PRESIDENT.—Do you wish an opinion expressed?

Mr. HAINES.—It is for the gentlemen who are more interested in the matter than I am to determine that.

The PRESIDENT.—If it is the desire that this meeting should express an opinion, it is very easily done; it can be done in two minutes.

Mr. CROWELL.—For the purpose of bringing it before the meeting, I move that the Board of Direction—I would add to this motion—a motion was made to refer to the Board of Direction and we are talking to that.

The PRESIDENT.—Let that pass; then you can if you wish say that it is the wish or the opinion of this meeting.

Mr. CROWELL.—Very well.

The PRESIDENT.—The motion is on the reference to the Board of Direction.

The motion, being duly seconded, was put to vote and carried.

Mr. CROWELL.—I move you, sir, that it is the sense of this meeting that it is desirable in the interest of the Society that the Board of Direction should memorialize Congress and send a committee to Congress to present the reasons why this Society and the membership it represents should be considered in the bill for the prosecution of any public work of the character of the proposed Isthmian Canal.

The PRESIDENT.—The chair thinks that that is an expression of instructions to the Board of Direction on a matter that has been referred to it, and is not in order. The only motion that can be made is the expression of an opinion by this meeting as to the desirability of the profession of civil engineering being represented in the management of the work in question. I think that it is not exactly courteous or proper for the Society at this meeting to instruct the Board of Direction as to matters that have been referred to it for consideration and action, and I cannot entertain that motion; but if it is a motion of an expression of opinion of this meeting, I will be glad to entertain it.

Mr. CROWELL.—The object of making the suggestion was merely to indicate what, in the sense of this meeting, was the shape that the action of the Board should take.

Employment of Engineers on Isthmian Canal (continued).

The PRESIDENT.—The sense of this meeting on the general subject?

Mr. CROWELL.—I think if that motion is read it will be found not to contain any offensive assumption, and as the meeting has been considered as the proper exponent of the views of the Society to control the individual action of its members, I do not see why we should not express our wishes to the Board.

E. P. NORTH, M. Am. Soc. C. E.—With a great deal of respect for you, personally, and for your office, Mr. President, I wish to take exception, directly, to your assertion that this meeting cannot instruct the Board of Direction.

The PRESIDENT.—I made no such ruling, sir.

Mr. NORTH.—I understood you to say so.

The PRESIDENT.—I said it was discourteous to the Board of Direction.

Mr. CROWELL.—I understood the Chairman to say that he would not entertain the motion. I think the wording will show that there is no discourtesy.

The PRESIDENT.—A motion of instruction to the Board of Direction as to how they are to act on a matter which is referred to them for consideration and action, I do not think is courteous or proper, and I rule that I will not receive such a motion or entertain it.

Mr. CROWELL.—I should like to have the resolution read.

Mr. NORTH.—I may be under a misapprehension, but I understood the motion to refer it to the Board of Direction was put through without any amendment to it. It was then, it seems to me, open to amendment. Now, I think that if it is not courteous to instruct the Board of Direction, we had better take that first motion back and reconsider it and embody in that the opinion of this meeting, which I think is always superior to the Board of Direction, creating the Board of Direction, as it does.

(The stenographer read the resolution.)

Mr. CROWELL.—I do not see how any expression of discourtesy is involved in that wording, and, if the Chair adheres to the opinion expressed, I appeal from the decision of the Chair.

The PRESIDENT.—The motion as read is different from what I understood it to be. The motion is that it is the opinion of this meeting that the Board of Direction ought to memorialize Congress.

Mr. OCKERSON.—I desire to endorse fully the statement made by Mr. Wallace, and also the statements made by Mr. Haines.

If the civil engineers do not look out for their own interests no one else will, and it seems to me that it is very important that they should be represented on any commission that is organized for the construction of an Isthmian Canal, and I am in favor of taking such action as may be necessary to call the attention of Congress to this phase of the matter.

The PRESIDENT.—I think that the matter can be simplified by omitting the Board of Direction from this resolution that has been offered, and make it simply an expression of opinion by the meeting, and I will be very glad if Mr. Crowell will withdraw the Board of Direction from his resolution.

Mr. CROWELL.—I am not prepared to do that. I think the Board of Direction is the body to look after this matter and see to its being carried out. I call for a vote on my motion.

Mr. GREEN.—May I suggest an amendment to this resolution by the omission of the words which make it general as to all great public works, and confine it to the Isthmian Canal for the present? It will be difficult to draw the line between small works and great works, and might embarrass the thing before Congress.

Mr. CROWELL.—I accept that. Cross out "any public works," and just make it refer explicitly to the Isthmian Canal.

M. R. SHERRERD, M. Am. Soc. C. E.—Can we, in any bill before Congress, mention the name of the Society? This would seem to indicate that we proposed to mention the name. I understand the motion intended that the Board of Direction should ask Congress to include, in any proposed bill, this Society—the membership of this Society.

Mr. WHINERY.—This motion is one which, if adopted, would mark a distinct departure from the long-established policy of the American Society of Civil Engineers. When it comes to the merits of the question as to whether the American Society of Civil Engineers and its members should be represented in the management of this, or any other great public work, no member of this Society shall go further than I in asserting that right, and that it is with entire propriety that the American Society of Civil Engineers and its members should be fully represented in every work of this kind, but, gentlemen, this involves more than that. It involves a step in a different direction from what the Society has ever taken heretofore. We have, up to this time, excluded from the policy of this Society everything savoring of commercialism, of business, and I do not think that such a measure should be taken now without very careful consideration. I do not believe that, on mature consideration, we would care to have the Society pose before Congress, or before the world, as seeking or demanding positions for its members, because, in the end, that is what it amounts to.

It is not this question directly that is before the Society, as I understand it, now. It is this broad general principle, shall this Society become an employment agency for the benefit of its members? I do not think the Society can afford to take such a position. I think we should, individually, make every proper effort to have this Society represented in all the great public works of the country, and par-

Employment of Engineers on Isthmian Canal (continued).

ticularly in this one, but, personally, I am bound to oppose any official action in that direction by the Society as a body. (Applause.)

H. G. Prout, M. Am. Soc. C. E.—I had intended to say what Mr. Whinery has said so much better than I could possibly say it. I thoroughly agree with the position that Mr. Whinery has taken. If we should send a committee to Congress it would be misunderstood. We could send that committee there with a full sense of the dignity of our position, the position of this Society, and the position of this profession, and Congress would not receive it in any such sense at all. They would receive that committee just as they receive everybody else who goes down to Washington asking for something. I think it would be most undignified and most unfortunate for this Society to send a committee to Congress to interfere in this matter at all.

As the thing stands, it is this way: The Hepburn Bill, the House Bill, puts the matter in the hands of the Secretary of War; the Morgan Bill, the Senate Bill, provides for a commission. I do not remember whether the Secretary of War is included in that commission *ex officio* or not, but I think not. It provides for the appointment of a commission which would be an experienced commission and which would make the conduct of this enterprise very largely a civil matter. I should say that the chances are that neither one of these bills will ever become a law. As it stands now, there is a most excellent chance that the Hepburn Bill will be very considerably modified, and the probability is that arrangements will be made so that the outcome will be such that this matter will be put in the hands of a civil commission; but, however that may be, that has nothing to do with the principle Mr. Whinery has so excellently expressed, and in which I so thoroughly agree. Therefore, I shall vote against this resolution.

Mr. Ockerson.—I wish to express my position in that matter. I agree pretty largely with what these gentlemen have said. The position I wish to take is this: I do not think the civil engineer should be excluded by law from any field of engineering. That is as far as I care to go. I do not care to advocate the employment of the members of this Society, but, for the great body of civil engineers, I do not want to see laws framed that will exclude them from any field of work.

Mr. Crowell.—As the author of the motion I wish to say that neither my friend, Mr. Whinery, nor my friend, Col. Prout, can go a step beyond me in the conservative desire to keep this Society from taking such a position before the world—before the population of our country. But I think this a different question altogether. It is true that in the past this Society has abstained from any attempt to push itself forward in the sordid way of getting employment for its members, but this is the first occasion when this country has undertaken to do work outside of the country, of this nature. It seems to

me eminently proper and advisable that at this juncture every effort should be made to have Congress and the people recognize the very principle which Mr. Whinery and Col. Prout have enunciated. It seems to me that to have a committee properly appointed, which could go down there and confer with the committee in charge of a bill, and represent to them the reasons why civil engineers should be considered, is not commercialism. I think it is a duty to our fellow countrymen that the country should have the advantage of having the participation of civil engineers. I think that while Mr. Whinery and Col. Prout have expressed themselves conservatively, they are yet taking a narrow stand on this question, and I hope the motion will prevail. It is not for a committee to go down advocating the employment of any individual or any number of individuals from the Society; they may not even require or request that a bill should call for such employment, but certainly the Society and what it represents should be represented in the conduct of work of that character. I hope the motion will prevail.

L. L. Tribus, M. Am. Soc. C. E.—I look upon the thing in somewhat the same way that two or three of the previous speakers have. If the members of the engineering profession of this country have not impressed upon the citizens of this country the need of their services in such matters as this, we do not deserve recognition, and I believe that Congress, if they pass such bills, appointing a commission, if the services of civil engineers are needed they will undoubtedly be called for. I think it would be very undignified for us to go and attempt to get this work. That is precisely what it means.

The President.—A number of military engineers, who are also members of this Society are present; we might hear from them.

Mr. Sherrerd.—When I spoke before on this subject, I did not make myself very clear. What I think would cover the point would be to substitute in this resolution for the words "this Society," the words "civil engineering profession." I do not think we want to take the position of relegating all the honors of the profession to ourselves, but the action coming from the American Society will reflect on the Society and will show that this Society stands up for the profession and wants to look out for the honors. That is the point.

Mr. Crowell.—I am perfectly willing to accept that change, substituting the name of the civil engineering profession in the place of the name of this Society; that is in accordance with the spirit of the resolution.

Mr. Green.—If the seconder of my proposed amendment will permit, I should like to include this proposed amendment and couple with it one to change the language so as to read as follows:

"It is the sense of this meeting that it is desirable in the interests of the Society that the Board of Direction should memorialize Congress

a committee to Congress to present the reasons why the civil engineering profession at large should be considered in the Bill for prosecution of work on the proposed Isthmian Canal."

Mr. Crowell.—It has been suggested to me that a further amendment of the language would be desirable, and, as I am very desirous of pleasing everybody, I will state what the suggestion is: That instead of expressing that as the sense of this meeting, to say that it is to the interests of the Society—while that is only an instruction to the Board of Direction, the suggestion that it should be the interests of this country, which is the more dignified plane to stand upon, and so, in my capacity of general agreer, I will accept that amendment—anything to get this matter before the Board.

J. F. O'Rourke, M. Am. Soc. C. E.—There seems to be a tendency to ignore the fact that all the work that has been done heretofore on this Isthmian Canal and on the canal question generally has been put in the hands of civil engineers, and it is to their great credit, I think, that nearly all of them are members of this Society. I think when you are trying to generalize at all, in order to generalize best you had better put the Society in, because there is hardly a man in the country who is recognized in the profession who is not a member of the Society, or would be if there were not a few of his friends who objected to it. I think, therefore, that all this question of looking for recognition and demanding that we have our rights, and not only that, but that we shall instruct the American people as to our great merits, and how foolish they would be if they did not call us in at good salaries, had better be dropped. As a matter of fact, we are always recognized, and any recognition that we get that is sought is not nearly as creditable to us as the recognition we have so far had unsought. I think the simplest way to get rid of the whole matter would be to have a vote on the broad question, or else lay it on the table.

Mr. Green.—Mr. O'Rourke is quite right, but if the Society is named in any resolution which is to be brought before Congress, Congress would be suspicious at once, and we had better say the civil engineering profession at large, which we know includes this Society and nobody else practically. It sounds better and would be more effective. I live in Washington.

Mr. Cooper.—Isn't it a little late in the day for members, going through the mathematical problems that we have, to try to establish an axiom? That is what I understand we are trying to do. We are trying to vote that we are an important body of men in this country, and that we are useful to our people. It seems to me that is an axiom, and self-evident. I would, therefore, move that this whole matter be laid upon the table.

Convention of 1903.

A MEMBER.—I second the motion.

The PRESIDENT.—A motion to lay on the table is always in order.

The motion, being put to a vote, was carried.

The SECRETARY.—The next business before the Society is a letter which the Secretary received from Roberto Gayol, M. Am. Soc. C. E.

MEXICO, December 27th, 1901.

CHARLES WARREN HUNT, Esq.,
New York, N. Y.

MY DEAR SIR,—I should be greatly obliged to you, if, at the next Annual Meeting of the Society, which will be held this year in New York, you would kindly propose that the next meeting, to be held in 1903, should be held in the City of Mexico, as the Mexican engineers would feel highly honoured in receiving a visit from the distinguished members of the American Society of Civil Engineers, and I feel no doubt that if this proposal is accepted, we will be able to make the visit pleasant to those gentlemen, and arrange some excursion, so as to enable them to see some of the principal points in the country.

Hoping my proposition will be accepted, I remain,

Yours very sincerely,

ROBERTO GAYOL.

The decision as to where the Convention of 1903 will be held will probably be placed in the hands of the Board of Direction; that is the way it has always been done before. I merely read this letter to the meeting as the gentleman requests.

The PRESIDENT.—The matter will take the usual course of correspondence.

Mr. OWEN.—Would it be out of order to offer a motion expressing the opinion of this meeting to the Board of Direction?

The PRESIDENT.—The meeting may express any opinion which is not in the nature of an instruction.

Mr. OWEN.—If it is in order, I would made a motion that it is the sense of this meeting that the most desirable place for the Annual Convention of 1903 would be in the City of Mexico.

The motion was seconded.

Mr. OCKERSON.—Is that motion before the house now?

The PRESIDENT.—I believe it was seconded.

Mr. OCKERSON.—I would like to call the attention of the Society to the fact that the great Louisiana Purchase Exposition is to be held in St. Louis in 1903.

Mr. OWEN.—I withdraw my motion, then.

The PRESIDENT.—The motion is withdrawn.

The SECRETARY.—I now have the report of the Tellers.

The PRESIDENT.—The report of the Tellers will now be read by the Secretary.

Report of Tellers.

Report of Tellers Appointed to Canvass the Ballot for the Election of Officers at the Annual Meeting, January 15th, 1902.

Whole number of ballots received	590
Without signature	11
Counted	579

For President:

Robert Moore	574
James D. Schuyler	2
Onward Bates	1
James William Way	1
George Y. Wisner	1
Defective	1

For Vice-Presidents:

John R. Freeman	569
Charles C. Schneider	572
Robert Moore	1
A. Mackenzie	2
Henry G. Prout	1
Adolphus Bonzano	1
Frank C. Osborn	1
Mansfield Merriman	1
Defective	2
Blank	1

For Treasurer:

Joseph M. Knap	579
Blank	1

For Directors:

District No. 1:

Richard S. Buck	572
John Bogart	1
F. Stuart Williamson	1
William P. Field	1
Nelson P. Lewis	1
Blank	2
Defective	1

District No. 1:

George H. Pegram	573
Josiah A. Briggs	1
Blank	5
Defective	1

District No. 1:

William J. Wilgus	566
George S. Rice	1
Louis L. Tribus	1
Alfred Craven	1
Clemens Herschel	1
Joseph O. Osgood	1
Alfred P. Boller	1
Francis T. Fisher	1
Blank	6
Defective	1

District No. 2:	
William Jackson	576
J. R. Worcester	1
Blank	2
Defective	1
District No. 3:	
Edmund F. Van Hoesen	575
William A. Haven	1
Blank	3
Defective	1
District No. 7:	
James L. Frazier	572
B. S. Wathen	1
A. J. Tullock	1
James D. Schuyler	1
James L. Lusk	1
D. C. Henney	1
William Wood	1
Blank	1
Defective	1

Respectfully submitted,

JOHN B. DUNCKLEE,
G. W. BRAMWELL,
Tellers.

JANUARY 15TH, 1902.

The PRESIDENT.—The following gentlemen are declared to be elected to the offices for which they were nominated: Robert Moore, President; C. C. Schneider, Vice-President; John R. Freeman, Vice-President; Joseph M. Knap, Treasurer; Directors, W. J. Wilgus, George H. Pegram, Richard S. Buck, William Johnson, E. F. Van Hoesen and J. L. Frazier.

The SECRETARY.—Although it has not been a matter of custom, it seems to me it would be a matter of courtesy to have a vote of thanks given to the tellers who have performed this arduous labor of counting the ballots for the last two or three hours.

Mr. GREEN.—I move that such a vote of thanks be given.

The motion, being duly seconded, was put to a vote and carried unanimously.

The SECRETARY.—Unless there is some new business, I would like to make one or two announcements.

The PRESIDENT.—Is there any other business before the house?

Mr. OCKERSON.—I have a resolution which I would like to offer:

Louisiana Purchase Exposition.

Resolved, That the American Society of Civil Engineers heartily favors the collection of a representative engineering exhibit for the Louisiana Purchase Exposition to be held in St. Louis in 1903, to illustrate in a creditable way the important part that the engineering profession has taken in the material progress of the country during the past century, and to this end we recommend the earnest co-operation of all members of this and other engineering societies.

The motion was seconded.

Louisiana Purchase Exposition (continued).

Mr. Ockerson.—I would like to explain the scope of the exposition, if I may be permitted, in about five minutes. I have written my remarks, in order that I might confine myself strictly to the text, and save your time.

I have the honor to represent the Department of Liberal Arts in the Louisiana Purchase Exposition, which has been inaugurated to celebrate in St. Louis the anniversary of the purchase of that vast territory formerly known as Louisiana.

This Exposition is international in character, and the President of the United States has invited all foreign governments to participate. The investment of the United States in this Exposition will exceed $6 000 000, and the City of St. Louis and the State of Missouri have pledged $11 000 000 more.

It is evident, therefore, that this is to be an exposition worthy of the event whose anniversary it celebrates.

There is no one transaction, in the stirring history of our country from its infancy down to the present time, that approaches in importance the acquisition of that great empire, with its wealth of minerals, soil and other natural resources.

In its development for the uses of man, the engineer has always been the pioneer. He has built railways across the trackless plains; he has tunneled the mountains; he has bridged the rivers; he has built storage reservoirs and irrigating canals which have made the desert plains to blossom with fertile fields and filled them with thrifty and happy homes. The greater part of this has been done within the past fifty years, and it is not too much to say that the engineer has made this remarkable progress possible, and to him should large credit be given.

It is especially fitting then, that the engineer should take the opportunity afforded by this exposition to show to the world how important his share of the work has been, and to fix a bench-mark from which the future progress of the profession can be measured.

The growth of the profession and its achievements during the past half century have been little less than marvelous.

The military school at West Point, not many years ago, was the only engineering school in the country. Now there are many well equipped schools of engineering throughout the length and breadth of the land, where students receive the most thorough training in all branches of civil engineering.

Not many years ago, Hasler was induced to come to this country to take charge of a very small department of the Government, charged with the survey of some of our harbors. There was not a single engineer in the country who was regarded as competent to conduct even that small work.

When Hasler appealed to the President for an increase in salary,

as engineers will do sometimes, even now, the President said: "Why, Mr. Hasler, I don't pay my Secretary of the Treasury more than I do you." Hasler replied, "That is all very well; you can get plenty of men for the post of Secretary of the Treasury, but there is only one Hasler—only one." It is needless to say that the increase of pay asked for was granted.

The same argument might not work quite as well to-day, as there would probably be another Hasler in the field.

I am extremely anxious to see our profession raised, in the esteem of the public, to the station held by the engineer in foreign lands, and it occurs to me that here is an opportunity to show to the public in an unmistakable way how large a share the engineer has had in the material progress of the country. If carried out in the proper way, it would do far more to establish the profession high up among the so-called learned professions, than any code of ethics that could possibly be devised.

I sincerely hope, therefore, that I will have the hearty co-operation of every member of the American Society of Civil Engineers, to the end that I may be able to secure a full line of exhibits, in the shape of models, drawings, maps and literature covering all fields of engineering and illustrating the progress made therein.

Gentlemen, an earnest effort on your part along the lines indicated, will not only be very gratifying to me, but it will, I am sure, be of substantial and lasting benefit to the engineering profession.

The following is a general outline of the engineering exhibits desired at the Louisiana Purchase Exposition.

Group 25, Civil Engineering.

Class 136. Building materials (other than timber), materials extracted from quarries, metals and ceramic products; lime, cement, plaster, artificial stone, etc. Equipment and methods of production of these materials.

Class 137. Methods of testing building materials.

Class 138. Preparation of building materials; implements and methods used by stone cutters, masons, carpenters, slaters, joiners, locksmiths, plumbers, glaziers, painters, etc.

Class 139. Equipment for and methods used in earth-work; hand tools, excavators, scrapers, barrows, dump-carts, service tracks, hand-carts, trucks, etc.

Class 140. Military defenses and accessories; engineering material employed in the operations of an army.

Class 141. Equipment for and methods used (other than pumps) for preparing foundations; piles, pile-drivers, screw-piles, pneumatic apparatus, etc.

Class 142. Equipment for and methods of transporting and distributing materials.

Class 143. Equipment and methods for the maintenance of roads, streets, promenades, etc.

Class 144. Equipment for lighting sea coasts, channels, mine-fields and beacons. Military and naval material for same.

Louisiana Purchase Exposition (continued).

Class 145. Equipment for and methods used in distributing water and gas (not including gas meters).
Class 146. Equipment for and methods used in pneumatic telegraphy

Group 26, Models, Plans and Designs for Public Works.

Class 147. Roads and other public highways on land. Bridges and viaducts.
Class 148. Inland navigation; improvement of rivers; construction of canals, dams, locks, lifts, fixed bridges, or draw-bridges, canal bridges, reservoirs and feeders; pumping stations, mechanical towing, and warping; equipment used for the development of river ports.
Class 149. Sea ports; general arrangements; jetties, basins, locks, swing bridges; equipment for development (not including shipping).
Class 150. Maritime canals.
Class 151. Irrigating canals and systems.
Class 152. Provision of lights and beacons for sea coasts.
Class 153. Protection against flooding by rivers or by sea.
Class 154. Railways as regards plan and profile of the line, and engineering works.
Class 155. Construction and maintenance of streets in cities.
Class 156. Water supply, sanitation and gas lighting of cities.
Class 157. Statistics, maps and publications relative to public works.

Group 27, Architectural Engineering.

Class 158. Models and plans of public buildings for special purposes; large and small dwelling houses.
Class 159. Models, drawings and specifications for foundations, walls, partitions, floors, roofs and stairways.
Class 160. Designs and models of special contrivances for safety, comfort, and convenience in the manipulation of elevators. doors, windows, etc.
Class 161. Working plans for the mason, carpenter and painter; designs and models of bonds, arches, coping, vaulting, etc.; plastering and construction of partitions; painting and glazing.

I thank you very much for the kind attention you have given me.

The President.—The question is on Mr. Ockerson's resolution that this meeting favors an exhibit at the Louisiana Purchase Exposition.

The motion being put to vote was carried.

Programme of the Annual Meeting.

The Secretary.—I have to announce that the programme of the Annual Meeting will be carried out as printed, with only one important change. The Reception will be held this evening, as scheduled, and to-morrow morning at 10 o'clock the party will leave the Society House to inspect the Rapid Transit work. After visiting the station at Fifty-ninth Street the party will inspect the work on Broadway, as far as Forty-second Street, and then along the latter to Park Avenue. On Park Avenue the upper tunnel heading, at Forty-first Street, will be visited, instead of the lower heading at Thirty-fourth Street, as at first intended.

From Forty-first Street the party will proceed to Delmonico's, at Forty-fourth Street and Fifth Avenue, and there take lunch with Mr. O'Rourke. The first intention was to have the lunch served in the vaults of the new Stock Exchange Building, but this has not been found practicable. After lunch the party will visit Mr. O'Rourke's work at the Stock Exchange and Hanover Bank Buildings.

In the evening the Smoker will be held at the Society House, as stated in the programme.

Invitation from Manhattan Railway Company.

The following letter has been received from Mr. George H. Pegram:

NEW YORK, January 14th, 1902.

CHARLES WARREN HUNT, Esq.,
Secretary,
American Society of Civil Engineers.

DEAR SIR,—The members of the Society attending the Annual Meeting are respectfully invited to visit the power station of the Manhattan Railway Company at Seventy-fourth Street and East River. Admission may be obtained by presenting badge at the door.

Yours respectfully,

GEO. H. PEGRAM,
Chief Engineer.

Announcements.

The SECRETARY,—There will be a meeting of the Board of Direction in the Secretary's office at 2 o'clock, and it is requested that every member of the Board present will attend promptly. The Constitution provides that there shall be nine members of the Board at meetings to be held at the Annual Meetings in order to make a quorum.

The PRESIDENT.—Is there any other business before the meeting? If not, a motion to adjourn is in order.

A MEMBER.—I move we adjourn.

The PRESIDENT.—I wish, gentlemen, to thank you for the courtesy that has been displayed to me. Success has attended our efforts during the past year to increase the Society and to have good meetings and valuable papers presented. Before I resign the gavel, I wish to introduce to you the only one of the newly elected Vice-Presidents who is present. We are very sorry that Mr. Moore is not present, or that Mr. John R. Freeman is not present, but we have with us Mr. C. C. Schneider.

I herewith tender to you, Mr. Schneider, the gavel, and I would say, in the words of a great author:

"It seems to me a message from the world of spirits when any man obtains that which he merits and in turn merits that which he obtains."

C. C. SCHNEIDER, Vice-President, Am. Soc. C. E.—I think it is not in the province of the Vice-President to make a speech; that honor belongs to the newly elected President, and as he is not here at the present time I prefer that he would make his own speech at the proper time.

The Society then adjourned.

EXCURSIONS AND ENTERTAINMENTS AT THE FORTY-NINTH ANNUAL MEETING.

Wednesday, January 15th, 1902.—After the business meeting, lunch was served at 1.30 P. M. in the Lounging Room. At 3 P. M. John F. O'Rourke, M. Am. Soc. C. E., described the foundation work on the new Stock Exchange Building and the new Hanover Bank Building, illustrating his remarks with lantern slides; and William Barclay Parsons, M. Am. Soc. C. E., described the main features of the Rapid Transit Tunnel Work, also using lantern slides to illustrate his remarks.

At 9 P. M. a reception was held in the Society House, which was very largely attended.

Thursday, January 16th, 1902.—At 10 A. M. the members met at the Society House, and, under the guidance of William Barclay Parsons, M. Am. Soc. C E., Chief Engineer of the Rapid Transit Commission, and the assistant engineers connected with the work, proceeded to inspect the Rapid Transit Work. The station at Broadway and Fifty-ninth Street and a portion of the tunnel to the south were lighted for the occasion. The various works on Broadway, south as far as Forty-second Street and along the latter street to Park Avenue, were visited. On Park Avenue, at Forty-first Street, the heading of the Park Avenue tunnel was inspected, and from this point the members proceeded to Delmonico's, at Forty-fourth Street and Fifth Avenue, where they were entertained at lunch by Mr. John F. O'Rourke.

After lunch, the party visited the new Stock Exchange and Hanover Bank Buildings and inspected the deep foundation work there under way.

In the evening there was an informal "Smoker" at the Society House.

The following list contains the names of 435 members of various grades, who registered as being in attendance at the Annual Meeting. This list is incomplete, on account of the failure of many members to register, and it does not include the names of any of the guests of the Society or of individual members:

Aiken, W. A......Pittsburg, Pa.
Allen, C. H.......New York City
Allen, W. A........Maurer, N. J.
Allen, W. H...New Haven, Conn.
Andrews, Horace...Albany, N. Y.
Asserson, P. C....Brooklyn, N.Y.
Averill, F. L...Washington, D. C.

Bacon, J. W.....Danbury, Conn.
Bailey, G. I........Albany, N. Y.
Baldwin, W. J.....New York City
Basinger, J. G....New York City
Baum, George...Bloomfield, N. J.
Belknap, W. E....New York City
Bellinger, L. F...Brooklyn, N. Y.
Benton, Lewis S...New York City
Berg, W. G.......New York City
Berger, Bernt.....New York City
Bettes, C. R......New York City
Beugler, E. J......Boston, Mass.

Binion, Joshua....New York City
Bishop, G. H. Middletown, Conn.
Bissell, H.........Boston, Mass.
Blakeley, G. H...Paterson, N. J.
Blakeslee, C...New Haven, Conn.
Blanchard, A. H. Providence, R. I.
Bogart, John.....New York City
Boller, A. P......New York City
Boller, A. P., Jr. East Orange, N.J.
Bond, Edward A .. Albany, N. Y.
Bonzano, A.....Philadelphia, Pa.
Bott, J. B.......Greensburg, Pa.
Bouton, G. H.....Boonton, N. J.
Bowman. A. L....New York City
Brackenridge, J.C. Brooklyn, N.Y.
Braine, L. F......New York City
Bramwell, G. W...New York City
Brendlinger, P.F. Philadelphia, Pa.
Breuchaud, J.....Yonkers, N. Y.
Brinckerhoff, H. W. New York City
Brinsmade, D. S....Derby, Conn.
Brooks, Fred......Boston, Mass.
Brown, Le Grand....Ithaca, N.Y.
Brown, Thomas E. New York City
Brush, W. W.....New York City
Buck, L. L.......New York City
Buck, R. S........New York City
Burden, J. A......New York City
Burdett, F. A....New York City
Bush, E. W..... Hartford, Conn.
Butts, E. P.......Holyoke, Mass.

Carr, Albert...East Orange, N. J.
Carter, S.........Richmond, Va.
Cattell, W. A.......New York City
Chapleau, S. J......Ottawa, Can.
Chase, J. C.........Derry, N. H.
Chase, R. D......New York City
Chester, J. N......Pittsburg, Pa.
Christian, G. L....New York City
Christy, G. L.....New York City
Clapp, O. F.....Providence, R. I.
Clark, G. H.......New York City
Clarke, John A., Jr. New York City
Clarke, St. J......New York City

Codwise, E. B....Kingston, N. Y.
Coffin, Amory.....New York City
Cogswell, W. B....Syracuse, N.Y.
Colby, S. K.......New York City
Cole, H. J........New York City
Collier, B. C......New York City
Collingwood, F...New York City
Conkling, L. de V..Elmira, N. Y.
Cook, John H......Passaic, N. J.
Cooke, C. H.......New York City
Cooper, Theo......New York City
Cornell, G. B.... New York City
Cornell, J. N. H....New York City
Coverdale, W. H..New York City
Crandall, C. L .... Ithaca, N. Y.
Crane, W. E......New York City
Craven, A.........New York City
Croes. J. J. R.....New York City
Crowell, Foster....New York City
Cuddeback, A. W..Paterson, N. J.
Cudworth, F. G...New York City

Darrach. C. G..Philadelphia, Pa.
Davies, J. V...... New York City
Davis, A. L.......New York City
Davis, Chandler...New York City
Davis, C. E......Montclair, N. J.
Davis, R. B........Boston, Mass.
Dean, Luther....Taunton, Mass.
Deans, J. S.... Phœnixville, Pa.
Devin, George.....New York City
Deyo, S. L. F.....New York City
Diebitsch, E......New York City
Dougan, J....... New York City
Drake, A. B..New Bedford, Mass.
Duncklee, J.B. South Orange, N.J.
Duryea, Edwin, Jr. Brooklyn, N.Y.

Easby, M. W...Philadelphia, Pa.
Edwards, J. H.....Oxford, N. Y.
Ehle, Boyd.....East Creek, N. Y.
Elliott, J. S...Washington, D. C.
Ellis, J. W.....Woonsocket, R. I.
Endemann, H. K..Brooklyn, N.Y.

Erlandsen, O......New York City
Evans, J. M......Brooklyn, N.Y.
Evans, M. E......New York City

Fairchild, John F. Mt. Vernon, N.Y.
Farley, J. M...White Plains, N.Y.
Farnum, H. H....New York City
Farrington, H.... New York City
Ferris, F. E....Jersey City, N. J.
Field, William P...Newark, N. J.
Fisher, Clark .... Trenton, N. J.
Fisher, F. D......New York City
Fisher, Wager..Philadelphia, Pa.
FitzGerald, J. L.
Schenectady, N. Y.
Foster, T. J.......New York City
Fouquet, J. D.....Fishkill, N. Y.
Francis, Geo. B..Providence, R. I.
Freeman, John R.
Providence, R. I.
French, A. H....Brookline, Mass.
French, J. B......New York City
Frick, Walter ...Carbondale, Pa.
Frost, G. H.......New York City
Frost, Geo. S.....New York City
Fuller, Geo. W....New York City
Fuller, W. B......New York City
Furber, W. C...Philadelphia, Pa.

Gardiner, F. W...New York City
Garrison, F. L..Philadelphia, Pa.
Gartensteig, C....New York City
Gay, C. W...... ...Lynn, Mass.
Gerber, E......Philadelphia, Pa.
Gifford, G. E......New York City
Gillespie, R. H... New York City
Goldsborough, J. B.
New York City
Gould, E. S........Yonkers, N. Y.
Gowen, C. S.....Ossining, N. Y.
Graham, J. M.....Baltimore, Md.
Granberry, J. H...New York City
Grant, T. H.....Red Bank, N. J.
Graves, E. D.....Hartford, Conn.
Gray, W..........New York City
Green, B. R...Washington, D. C.
Greene, Carleton..New York City
Greene, F. S......New York City
Greene, G. S., Jr..New York City
Gregory, C. E.....New York City
Greiner, J. E.....Baltimore, Md.

Hague, Chas. A...New York City
Haight, S. S......New York City
Haines, C W...Philadelphia, Pa.
Haines, H. S......New York City
Hall, M. W ... .New York City
Hammer, R. H...Brooklyn, N. Y.
Hankinson, A. W..New York City
Harby, I..........New York City
Harding, W. S..Philadelphia, Pa.
Hardy, G. R...Forest Hills, Mass.
Harrington, F. F. Brooklyn, N. Y.
Harrington, J. L..New York City
Harris, C. M .... New York City
Harrison, A. W. .. ....Erie, Pa.
Harwi, S. J.......Bayonne, N. J.
Haskins, W. J.....New York City
Hauck, W........New York City
Haviland, A.......New York City
Hayes, E..........Cohoes, N. Y.
Hayes, S. W.......Newark, N. J.
Hazen, Allen......New York City
Hazelton, C. W.
Turners Falls, Mass.
Hemming, D. W...New York City
Hendrick, C. W...New York City
Henry, P. W......New York City
Herbert, H. M. Bound Brook, N. J.
Hering, Rudolph..New York City
Hickok, H. A.. ...Newark, N. J.
Hill, A. B......New Haven, Conn.
Hill, Geo.........New York City
Hinds, F. A....Watertown, N. Y.
Hoag, S. W., Jr...New York City
Hodge, H. W.....New York City
Hoff, Olaf.........New York City
Hoffman, N. B. K..New York City
Honness, G. G....Paterson, N. J.
Hook, C. A.......Baltimore, Md.

Horton, S.....Indianapolis, Ind.
Horton, Theo.....New York City
Hough, D. L......New York City
Hovey, O. E........Pencoyd, Pa.
Howe, H. J.......New York City
Hoyt, J. T. N.....New York City
Hoyt, William E. Rochester, N. Y.
Humphrey, R. L. Philadelphia, Pa.
Hunt, Charles Warren New York City
Hunt, R. W.........Chicago, Ill.
Hunter, R. E...Montreal, Canada
Hurry, E. H......Bethlehem, Pa.
Hyde, A. L....New Haven, Conn.

Irving, W. E......New York City

Jackson, J. M..Schenectady, N. Y.
Jacoby, H. S........Ithaca, N. Y.
Johnson, Alex.....New York City
Johnson, L. J...Cambridge, Mass.
Jonson, Ernst.....New York City

Kaufman, G.......New York City
Kelley, J. A....Philadelphia, Pa.
Kelley, W. D......New York City
Kenly, W. L......Baltimore, Md.
Kennedy, John. Montreal, Canada
Kenney, E. F...Philadelphia, Pa.
Khuen, R., Jr......Pittsburg, Pa.
Kimball, Geo. A...Boston, Mass.
King, Paul S.......New York City
King, Wallace, Jr. New York City
Kingsley, T. P....New York City
Klapp, Eugene....New York City
Knap, E. D.......New York City
Knap, J. M.......New York City
Knight, F. B......New York City
Kuichling, E....Rochester, N. Y.

Landreth, O. H.....Ithaca, N. Y.
Langton, John....New York City
Lant, F. P........New York City
Lea, S. H .....Birmingham, Ala.
Leavitt, C. W., Jr. New York City
Leavitt, F. M.....New York City
Lee, W. B........New York City
Leffingwell, F. D..New York City
Lehlbach, G.......Newark, N. J.
Leonard, H. R..Philadelphia, Pa.
Lewis, N. P......Brooklyn, N. Y.
Lindenthal, G.....New York City
Livingston, J. I. Bound Brook, N. J.
Long, E. McL.....New York City
Loomis, Horace....New York City
Low, G. E.........New York City
Lowinson, O......New York City
Ludwig, A.........New York City
Lundie, John ....New York City
Luster, W. H., Jr. Elizabeth, N. J.

Macdonald, A. A..New York City
Macdonald, C ....New York City
Machen, H. B.....New York City
Macnab, G. T.....New York City
McCann, T. H....Hoboken, N. J.
McComb, C. O..Watertown, N. Y.
McGregor, R. A...New York City
McKenna, C. F....New York City
McKenzie, T. H..Hartford, Conn.
McKim, A. R.....New York City
McMinn, T. J.....New York City
McNicol, J. A.....New York City
McNulty, G. W...New York City
Magor, H. B......New York City
Malukoff, A. J....New York City
Manley, H.........Boston, Mass.
Marden, H. H., Jr. New York City
Marple, W. McK...Scranton, Pa.
Martin, C. C......New York City
Martin, K. L.....Brooklyn, N. Y.
Martin, W. B.....New York City
Mayer, Joseph....New York City
Mead, C. A........Newark, N. J.
Mead, E......Washington, D. C.
Meem, J. C.......New York City
Merryman, W. C..New York City
Metcalf, L....Washington, D. C.

Meyer, H. C......New York City
Miller, H. A.......Clinton, Mass.
Miller, R. P.......New York City
Mills, C. M....Philadelphia, Pa.
Miner, C. A...Washington, D. C.
Moore, C. H......New York City
Moore, W. H..New Haven, Conn.
Morse, C. M.......Buffalo, N. Y.
Moses, P. R.......New York City
Myers, C. H.......New York City

Neumeyer, R. E..Bethlehem, Pa.
Nichols, C. H..New Haven, Conn.
Nichols, O. F....Brooklyn, N. Y.
North, E. P.......New York City
Nostrand, P. E....New York City
Nye, A. S ....New York City

Oastler, W. C.....New York City
O'Brien, J. H...Providence, R. I.
Ockerson, J. A.....St. Louis, Mo.
Odell, F. S........New York City
Olcott, E. E.......New York City
Olney, L. F.......New York City
O'Rourke, J. F....New York City
Osgood, J. O......New York City
Owen, Jas.........Newark, N. J.

Parker, A. McC...New York City
Parsons, H. de B..New York City
Parsons, W. B....New York City
Patterson, J. A..Philadelphia, Pa.
Pegram, G. H.....New York City
Perkins, P. S...Providence, R. I.
Pierce, W. T.......Boston, Mass.
Piper, A. R........Ossining, N. Y.
Pitts, T. D.... .. New York City
Polk, W. A........New York City
Pollock, C. D.....New York City
Potter, Alex.......New York City
Pratt, W. A.....Philadelphia, Pa.
Prince, A. D......New York City
Prout, H. G.......New York City
Pruyn, F. L.......New York City

Raasloff, H de ....New York City
Ramsey, E. P.... New York City
Reed, W. B......New York City
Reynolds, J. O....New York City
Rhodes, F. D.....New York City
Rice, G. S........New York City
Richardson, C....New York City
Richardson, T. F..Clinton, Mass.
Ricketts, P. C.......Troy, N. Y.
Ridgway, R......New York City
Ritchie, J. .. Cleveland, Ohio
Roberts, P., Jr.Philadelphia, Pa.
Rosenberg, F.....New York City
Rosenthal, A...Mt. Vernon, N. Y.
Rotch, W..........Boston, Mass.
Rowland, T. F....New York City
Ryan, M. H.......New York City
Ryder, E. M. T..New Haven, Conn.

Sabin, A. H.......New York City
Saunders, W. L...New York City
Schmitz, F. C.....New York City
Schneider, A......New York City
Schneider, C. C.Philadelphia, Pa.
Schwiers, F. W....New York City
Seaman, H. B.....New York City
Shaler, I. A.......New York City
Sherrerd, M. R....Newark, N. J.
Shryock, J. G., Jr.
Philadelphia, Pa.
Simpson, G. F.....New York City
Skinner, F. W.....New York City
Smith, C. W......New York City
Smith, E. R..........Islip, N. Y.
Smith, J. W......Paterson, N. J.
Smith, L. C. L.
Long Island City, N. Y.
Smith, W. F......New York City
Snow, J. P.........Boston, Mass.
Sooysmith, C.....New York City
Soper, G. A.......New York City
Stanton, F. McM.
Atlantic Mine, Mich.
Stanton, R. B.....Sewickley, Pa.
Stearns, F. P......Boston, Mass.
Stern, E. W.......New York City
Stevens, A.........New York City
Stidham, H.......New York City

Stiger, J. S , Jr..Mendham, N. J.
Stoddard, G. C....New York City
Stowe, H. C......New York City
Stuart, A. A........Quebec, Can.
Swindells, J. S..Mt. Kisco, N. Y.

Taber, G. A.......New York City
Taylor, C. F..East Boston, Mass.
Taylor, L. A...... Boston, Mass.
Thomas, G. E....Annapolis, Md.
Thomes, E. H.....New York City
Thompson, S. C...New York City
Thompson, S. E.
Newton Highlands, Mass.
Thomson, A., Jr..New York City
Thomson, G. H.:.Ossining, N. Y.
Thomson, T. K...New York City
Thornley, J.......New York City
Tibbals, G. A.....New York City
Tibbals, S. G.....New York City
Tilden, C. J.......New York City
Tomlinson, A. T...Boston, Mass.
Tompkins, E. DeV.
New York City
Tompson, G. M....Boston, Mass.
Travell, W. B.....New York City
Treadwell, L...Portsmouth, N. H.
Tribus, L. L.......New York City
Triest, W. G. F....New York City
Trotter, A. W......New York City
Tucker, L. W.....Boston, Mass.
Tucker, W. C.....New York City
Turner, D. L......New York City
Tuska, G. R......New York City

Ulrich, D.........New York City
Upham, C. C.....New York City
Upham, R. D......New York City

Value, B. R ......New York City
Van Horne, J. G..New York City
Van Orden, C. H..Catskill, N. Y.
Van Winkle, E. B..New York City
Vielé, M. A....Schenectady, N. Y.
Vier, H..........New York City
Vorce, C. B .....Hartford, Conn.
Vredenburgh, W., Jr.
New York City

Waddell, M.......New York City
Wadsworth, J. E..New York City
Wagner, J. C...Philadelphia, Pa.
Wait, J. C........New York City
Ward, C. R.......New York City
Ware, R. W.....Plainfield, N. J.
Wason, L. C.......Boston, Mass.
Waterhouse, J....New York City
Watkins, F. W.White Plains, N.Y.
Webb, W. L....Philadelphia, Pa.
Webster, A. L....New York City
Webster, G. S..Philadelphia, Pa.
Webster, W. R...Philadelphia, Pa.
Wegmann, E.....Katonah, N. Y.
Wells, C. E.......Clinton, Mass.
Wells, J. A.......New York City
Wells, J. H.......New York City
Wheeler, S. S.....New York City
Whinery, S........New York City
Whipple, G. C...Brooklyn, N. Y.
White, F. G......New York City
White, L.........New York City
White, T. S.....Beaver Falls, Pa.
Whitney, F. O.....Boston, Mass.
Whitson, A. U....New York City
Whittemore, W. F.New York City
Wiggin, E. W..New Haven, Conn.
Wilcock, F........New York City
Wiley, W. H......New York City
Williamson, F. S..New York City
Willson, F. N....Princeton, N. J.
Wilson, C. W. S.
New Rochelle, N. Y.
Wölfel, Paul L......Pencoyd, Pa.
Woodbury, C. J. H.Boston, Mass.
Wortendyke, N. D.
Jersey City, N. J.
Wright, J. B......New York City

York, H. W.......New York City

Zollinger, L. R.Philadelphia, Pa.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, March 5th, 1902.—8.30 P. M.—At this meeting ballots for membership and ballots on the proposed Amendment to the Constitution will be canvassed, and a paper by George S. Morison, Past-President, Am. Soc. C. E., entitled "The Bohio Dam," will be presented for discussion.

This paper was printed in the *Proceedings* for January, 1902.

Wednesday, March 19th, 1902.—8.30 P. M.—At this meeting a paper by C. A. P. Turner, M. Am. Soc. C. E., entitled "Thermo-Electric Measurement of Stress," will be presented for discussion.

This paper was printed in the *Proceedings* for January, 1902.

Wednesday, April 2d, 1902.—8.30 P. M.—At this meeting ballots for membership will be canvassed, and two papers will be presented: one by Marsden Manson, M. Am. Soc. C. E., entitled "A Brief History of Road Conditions and Legislation in California," and the other by Charles C. Wentworth, M. Am. Soc. C. E., on "Line and Surface for Railway Curves."

These papers are printed in this number of *Proceedings*.

Wednesday, April 16th, 1902.—8.30 P. M.—At this meeting two papers will be presented for discussion, as follows: "Is It Unprofessional for an Engineer to be a Patentee?" by Archibald R. Eldridge, M. Am. Soc. C. E.; and "The Stiffening System of Long-Span Suspension Bridges for Railway Trains," by Joseph Mayer, M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings*.

ANNUAL CONVENTION OF 1902.

The Thirty-fourth Annual Convention of the Society will be held at Washington, D. C., beginning on Tuesday, May 20th, 1902.

CURRENT ENGINEERING LITERATURE.

The interest which has been manifested in this monthly list of references has led the Committee on Publications to decide that hereafter this list shall be printed on one side of the page only. Several mem-

bers have asked that this be done so that anyone may cut out, for scrap-book or card-index use, that part of the classified list which may be of special interest to himself.

That this publication has proved of service to members is gratifying. It often takes a long trial to ascertain whether money expended in new ways is well spent, for the reason that expressions of approval seem to members to be gratuitous and unnecessary, and are, consequently, not often heard. It is therefore suggested that interest in the publications which is manifested by suggestions for improvement which are to the point will always be received with appreciation by the Committee on Publications.

PRESENTATION OF PAPERS.

It will be noticed that a new departure has been made in assigning the dates for the presentation of the four papers printed in this number, two of them having been scheduled for the first April meeting, and two for the second meeting of that month. The increasing number of papers makes this policy necessary, and inasmuch as the practice of the reading in full of any but an extremely short paper has been abandoned, it is hoped that added interest in meetings will result in the discussion of more than one subject in one evening. The Committee on Publications some time ago authorized the Secretary to request, when in his judgment it was advisable, that the author of an accepted paper prepare an abstract of it which in his absence might be read to the meeting by the Secretary. The Committee has not cared to require such an abstract, feeling that the furnishing of it should be optional with the author. Sooner or latter it will be necessary to present all papers briefly, in order to secure proper time for discussion, and it is here suggested that a brief abstract, either of a paper or of a long written discussion, giving the premises on which argument is based, or the general results of mathematical or experimental investigation, and the author's conclusions, will always be acceptable, and can be used to the advantage of members who attend the meetings, not only in concentrating attention on the subject, but in the suggestion of new ideas which may add to the interest of the verbal discussion which follows.

TOPICS FOR DISCUSSION AT THE ANNUAL CONVENTION.

It will be remembered that at the last three Conventions no formal papers have been presented, but that in their stead topics of general interest have been presented for discussion. The resulting attendance and interest in convention meetings has shown the wisdom of the change, and the Committee on Publications will be glad to have members suggest topics suitable for discussion.

The following list of the subjects which have already been discussed at Conventions, is here printed, in order to give some idea of the kind of subjects desired :

LIST OF SUBJECTS PRESENTED FOR DISCUSSION AT THE LAST THREE ANNUAL CONVENTIONS.

"Should the use of the method of Wheel Concentrations be discontinued in determining the Stresses in Railroad Bridges?

"In view of present knowledge of the Effect of Repeated Applications of Load, should Fatigue Formulas be used in Bridge Design?

"(*a*) Should Stream Contamination by the Sewage of Cities be absolutely prohibited by law?

"(*b*) Should the Purification of the Sewage of Cities be compulsory, and is this feasible for Large Cities?

"(*c*) Is Filtration the coming solution of the Pure-Water Question for Cities?

"What is the Proper Friction Coefficient for use in the design of Riveted Steel Pipe?

"What are the economic conditions under which Electricity may be profitably substituted for Steam in the operation of Branch Railroad Lines, and what are the engineering requirements to be considered in such substitution?

"What is the present development of the so-called Telferage System for moving either Freight or Passengers? What are the conditions under which that System is preferable to movement by Rail, and what is its adaptability to still further application in competition with Rail Lines?

"Height of Buildings.

(1) What considerations should limit the height of buildings?

(2) Do recent developments in construction, sanitation, intercommunication and economy of administration, warrant the removal of all restrictions?

"Recent Practice in Rails.

The progressive increase in weight; the increase in hardness, particularly in carbon; the sections in most general use; the effect of changes in weight, composition and section.

"Filtration of Water for Public Use.

The several processes now used for the removal of objectionable matter; their comparative sanitary effect, cost and reliability.

'Do the interests of the profession, and the duty of its members to the public, require that only those who are competent be allowed to practice as Civil Engineers? Under what authority, through what agency, and upon what evidence of competency, should applicants be admitted to the practice of Civil Engineering?

"Steel-Concrete Construction.

What stress in tension and compression should be allowed in concrete?

What is the proper modulus of elasticity of concrete?

In Steel-Concrete Arches:

(1) What should be the ratio of steel section to concrete section, section, and what is the best form and disposition of the the former?

(2) What consideration should be given to temperature changes and consequent stresses?

(3) What are the best proportions for concrete, and what is the the best method of placing it?"

"The Decolorization of Water.

When is it necessary? How may it be accomplished?"

"The Consumption of Water in Municipal Supplies and the Restriction of Waste."

SEARCHES IN THE LIBRARY.

As stated in the Annual Report, the Board of Direction has directed the Secretary to make a charge for such library searches and correspondence as do not fall within the regular duties of employees, which shall cover the actual cost of any extra work undertaken for an individual.

The only difficulty about this matter seems to be the impossibility of fixing in advance the scope and cost of any such search. It can only be said in general that the time of an employee competent to do such work is paid for by the Society at from 30 to 40 cents per hour, and that to this must be added the actual cost of typewriting.

Inasmuch as this idea was adopted experimentally, in the belief that it would prove of value to non-resident members, and as it is not the intention to realize any profit, it would seem that, in asking that such searches be made, the risk is not great, particularly as a limit of the total expense to be incurred might easily be specified by the member.

ACCESSIONS TO THE LIBRARY.

DONATIONS.*

(From January 8th to February 11th, 1902.)

THE MECHANICS OF ENGINEERING.

Volume I. Kinematics, Statics, Kinetics, Statics of Rigid Bodies and of Elastic Solids. By A. Jay Du Bois. Cloth, 11 × 8 ins., 34 + 634 pp., illus. New York, John Wiley & Sons, 1902. $7.50.

This work is presented as the first volume of a series dealing with the applications of mechanics to engineering problems. It opens with a presentation of the fundamental principles of kinematics, statics and kinetics; then follow the practical applications. Throughout the work numerous problems and illustrative examples are given in direct connection with each important mechanical principle. In these applications the author has included the results of his own work in this direction, and he believes that the professional reader will find here new and valuable discussions of engineering problems, especially in the chapters on Masonry Walls and Dams, the Strength of Long Columns, the Swing Bridge, the Metal Arch, the Suspension System and the Stone Arch. There is an index of eight pages.

MUNICIPAL ENGINEERING AND SANITATION.

By M. N. Baker. ½ Leather, 8 × 5 ins., 8 + 317 pp. New York, The Macmillan Company, 1902. $1.25.

This volume is intended for that class of persons who, either as officials or as citizens, are striving to improve municipal conditions. It is designed to be a review of the whole field of municipal engineering and sanitation rather than an exhaustive study of one or a few branches of the subject. The most vital points, however, under each class of activities and interests have been dwelt upon, the underlying principles stated, and in many instances details from actual practice given. The preface states that while it is not expected that engineers and sanitarians will find in the book much relating to their specialties that is new to them, it is believed that the number and variety of subjects treated, and the comparative newness of some of the topics, will make the book helpful even to professional men. The Contents are: Introduction; Ways and Means of Communication; Municipal Supplies; Collection and Disposal of Wastes; Protection of Life, Health and Property; Administration, Finance and Public Policy. There is an index of six pages.

FOWLER'S ELECTRICAL ENGINEERS' YEAR BOOK

And Pocket Directory of Light, Power and Traction Stations. 1902. Leather, 6 × 4 ins., 429 pp., illus. Manchester, Scientific Publishing Company. 2 shillings, 9 pence.

In this second issue of the electrical handbook the scope of information has been considerably enlarged. The directory of technical information respecting the equipment of the various central electric light, power and traction stations in the United Kingdom has been thoroughly revised and brought up to date, in nearly every case having been personally checked by the engineer in charge. There is an index of twenty-four pages.

CROQUIS DE PONTS MÉTALLIQUES.

Par Jules Gaudard. Paper, 13 × 10 ins., 158 pp., plates. Paris, Ch. Béranger, 1901. (Donated by the Author.)

The Contents are: Ponts en Métal Moulé; Ponts en Fer ou Acier Laminé; Levage des Ponts Métalliques; Reception et Surveillance des Ponts. Poids des Fers. There is an index of four pages.

WASSERVERHÄLTNISSE DER SCHWEIZ.

Bearbeitet und herausgegeben von der hydrometrischen Abteilung des eidg. Oberbauinspektorates. Paper, 14 × 10 ins., 3 vols., plates. Berne, 1896–1901. (Donated by Hydrometrische Abteilung des eidg. Oberbauinspektorates in Berne.)

The Contents are: Rheingebiet von den Quellen bis zur Taminamündung; Erster Teil—Die Flächeninhalte der Einzugsgebiete, der Höhenstufengebiete von 300 zu 300 m.

* Unless otherwise specified, books in this list have been donated to the Library by the Publisher.

über Meer, der Felshänge, Wälder, Gletscher und See'n; Zweiter Teil.—Die Pegelstationen hinsichtlich ihrer Anlage und Versicherung, sowie Darstellung der dazugehörenden Durchflussprofile und Relativen Wasserspiegelgefälle; Dritter Teil.—Die Längenprofile der fliessenden Gewässer unter specieller Berücksichtigung der ausgenützten und der für neue Wasserkraft-Anlagen noch verfügbaren Strecken, nebst typischen Querprofilen und den Höhenversicherungen; A. Vorder-Rhein und seine bedeutenderen Zuflüsse. Rhonegebiet von den Quellen bis zum Genfer-See; Erster Teil—Die Flächeninhalte der Einzugsgebiete, der Höhenstufengebiete von 300 zu 300 m. über Meer, der Felshänge, Wälder, Gletscher und See'n; Zweiter Teil—Die Pegelstationen hinsichtlich ihrer Anlage und Versicherung, sowie Darstellung der dazugehörenden Durchflussprofile und relativen Wasserspiegelgefälle.

THE TRANSITION CURVE OR CURVE OF ADJUSTMENT.

By the Method of Rectangular Co-ordinates and by Deflection Angles (Polar Co-ordinates). Based on the French of M. Nordling, with Additional Problems by N. B. Kellogg, M. Am. Soc. C. E. Cloth, $6\frac{1}{2} \times 4$ ins., 2 + 60 pp. San Francisco, N. B. Kellogg, 1899.

The following gifts have also been received:

Am. Inst. of Elec. Engrs. 1 bound vol.
Am. Inst. of Min. Engrs. 18 pam.
Assoc. of Ry. Supts. of Bridges and Buildings. 1 pam.
Brooklyn Engrs.' Club. 1 bound vol.
Budge, Enrique. 90 bound vol., 15 vol., 117 pam.
Chickamauga Park Comm. 1 atlas.
Colo. Agricultural Exper. Station. 1 pam.
Conn. R. R. Commrs. 1 bound vol.
Corthell, E. L. 2 pam.
Eckel, Edwin C. 1 pam.
Greenhalge, F. B. 2 bound vol.
Harrod, B. M. 4 bound vol.
Hutton, N. H. 1 pam.
Ill. Agricultural Exper. Station. 4 pam.
Inst. of Civ. Engrs. 2 pam.
Inst. of Marine Engrs. 1 bound vol.
Iron and Steel Inst. 1 bound vol., 1 pam.
Jackson, William. 57 pam.
Kernot, W. C. 2 pam.
Kummer, F. A. 1 bound vol.
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Nicholson, G. B. 8 bound vol., 1 vol., 13 pam.
Ockerson, J. A. 3 pam.
Oesterreichischer Ingenieur- und Architekten-Verein. 2 nos.
Penn. Univ. 1 vol.
Platt, T. C. 3 vol., 1 pam., 1 atlas.
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BY PURCHASE.

Electrical Engineer's Pocket-Book. A Hand-Book of Useful Data for Electricians and Electrical Engineers. By Horatio A. Foster, M. A. I. E. E.; M. A. S. M. E. New York, D. Van Nostrand Company. London, E. & F. N. Spon, Ltd., 1901.

The Mineral Industry, Its Statistics, Technology and Trade in the United States and Other Countries, 1893–1899. Edited by Richard P. Rothwell. Vols. 2–8. New York and London, The Scientific Publishing Company, 1894–1900.

Handbuch der Ingenieurwissenschaften. Third Edition, Enlarged. 2 vols. Leipzig, Wilhelm Engelmann, 1901.

Lehrbuch der Meteorologie. Von Dr. Julius Hann. Leipzig, Chr. Herm. Tauchnitz, 1901.

The Universal Directory of Railway Officials, 1901. Compiled from Official Sources under the Direction of S. Richardson Bludstone. London, The Directory Publishing Company, Limited, 1901.

Centralblatt der Bauverwaltung (to complete set). 44 nos.

Transactions of the North of England Institute of Mining and Mechanical Engineers (to complete set). 13 vol.

SUMMARY OF ACCESSIONS.

January 8th to February 11th, 1902.

Donations (including 126 duplicates and 2 numbers completing volumes of periodicals)	355
By purchase (including 44 numbers, completing volumes of periodicals)	66
Total	421

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
ABBOTT, ARTHUR VAUGHAN, Room 209, Electrical Bldg., Cleveland, Ohio.....	Jun. M.	Jan. 5, 1881 Dec. 4, 1901
BUDGE, EDWARD BARNARD, Eng. in Chf., 1st Section, Chili State Railways (F. C. de E.), Estacion Bella Vista, Valparaiso, Chili............		Nov. 6, 1901
CHASE, CHARLES FRANCIS Chf. Eng., Berlin Constr. Co., 241 West Main St., New Britain, Conn....................		Feb. 5, 1902
ELLIS, GEORGE EZRA, Signal Eng., Standard Signal Co., Troy, N. Y............		Dec. 4, 1901
HILDENBRAND, WILHELM 1 Broadway, New York City...........................		Feb. 5, 1902
KADONO, CHOKURO, Eng. and Mgr., Okuro & Co., 53 New Broad St., London, E. C., England.......................		Jan. 8, 1902
SNOW, WILLIAM PLINY, 335 Lexington St., Auburndale, Mass...................		Feb. 5, 1902

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BRANCH, THOMAS PETTUS Jun. Prof., Georgia School of Technology, Atlanta, Ga...		Feb. 5, 1902
BURDEN, JAMES 3 Locust Ave., Troy, N. Y..............................		Feb. 5, 1902
COWPER, JOHN WHITFIELD, Eng. and Supt., British Westinghouse Elec. & Mfg. Co., Ltd., Mersey Tunnel Ry. Impvmts., Birkenhead, England....	Jun. Assoc. M.	June 21, 1894 Oct. 2, 1901
DU BOIS, JULIAN, Supt., Amsterdam St. R. R., Amsterdam, N. Y..........		Jan. 8, 1902
EDWARDS, FREDERICK, Instr. in Civ. Eng. and Math., Union College, Schenectady, N. Y......................	Jun. Assoc. M.	Jan. 31, 1899 Feb. 5, 1902
FAY, EDWARD BAYRD, 1000 Fullerton Bldg., St. Louis, Mo.....................		Jan. 8, 1902
FLYNN, JOHN, Jr., 83 Third St., Troy, N. Y..............................		Jan. 8, 1902
HARWOOD, GEORGE ALEC, Chf. Draftsman, N. Y. C. & H. R. R. R., Room 521, Grand Central Station, New York City.......................		Feb. 5, 1902

Name and Address	Grade	Date of Membership.
Hone, Frederic de Peyster, (Chambers & Hone), 60 New St., New York City	Jun. Assoc. M.	April 4, 1899 Feb. 5, 1902
McGilvray, Thomas Forrester, 209 First Natl. Bank Bldg., Duluth, Minn.		Feb. 5, 1902
Newton, Ralph Ellis, P. O. Box 1098, Milwaukee, Wis.		Jan. 8, 1902
Pollock, Clarence Du Bois, Sen. Asst. Eng., Sewer Div., N. Y. Rapid Transit R. R. Comm., 13 Astor Pl., New York City		Jan. 8, 1902
Reid, Homer Austin, 169½ Columbia Heights, Brooklyn, N. Y.		Dec. 4, 1901
Sears, Robert Humphrey, Care, Chf. Eng., East Indian Railway Office, Calcutta, India		Dec. 4, 1901
Smith, William Stuart, 59 West Main St., Rochester, N. Y.		Jan. 8, 1902
Stratton, George Eber, U. S. Hydrographer, Room 1014, Barristers' Hall, Boston, Mass.		Jan. 8, 1902
Tilden, Charles Joseph, Asst. Eng., N. Y. Rapid Transit R. R. Comm., 1161 Amsterdam Ave., New York City	Jun. Assoc. M.	May 31, 1898 Feb. 5, 1902
Trout, Charles Eliphalet, Dept. of Docks and Ferries, Pier A, North River, New York City	Jun. Assoc. M.	Oct. 31, 1899 Jan. 8, 1902
Weston, Robert Spurr, 14 Beacon St., Boston, Mass.		Feb. 5, 1902
Wilson, Percy Hartshorne, Secy. and Treas., River & Harbor Impvmt. Co., 801 Drexel Bldg., Philadelphia, Pa.	Jun. Assoc. M.	Jan. 2, 1900 Feb. 5, 1902

ASSOCIATE.

Name and Address	Date of Membership.
Bennett, Leslie J., Secy., Buffalo Cement Co., Ltd., 110 Franklin St., Buffalo, N. Y.	Jan. 7, 1902

JUNIORS.

Name and Address	Date of Membership.
Burwell, Robert Lemmon, New London, N. C.	Dec. 3, 1901
Falk, Myron Samuel, Tutor, Dept. Civ. Eng., Columbia Univ., Res. 63 East 74th St., New York City	Feb. 4, 1902
Hammer, Robert Henry, 4 Dean St., Brooklyn, N. Y.	Jan. 7, 1902

	Date of Membership.
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518 Broad St., Newark, N. J.	Dec. 3, 1901
POTTS, CLYDE,	
U. S. Engrs.' Office, 33 Campau Bldg., Detroit, Mich.	Dec. 3, 1901
THOMPSON, WILFORD ASHFORD,	
Asst. Engr., Board of Public Works, 108 S. Conception St., Mobile, Ala	Oct. 1, 1901
UNDERWOOD, HOWARD WARREN,	
811 NORTH 41st St., Philadelphia, Pa.	Dec. 3, 1901
WHITE, FRANK GEORGE,	
316 West 115th St., New York City	Dec. 3. 1901
WHITSON, ABRAHAM UNDERHILL,	
College Point, Long Island, N. Y.	Jan. 7, 1902
WILCOCK, FREDERICK,	
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WINCHESTER, PHILIP HAROLD,	
20 Winslow St., Watertown, N. Y.	Jan. 7, 1902

RESIGNATIONS.

ASSOCIATE MEMBER.	Date of Resignations.
STOUT, EDMUND COFFIN	Feb. 4, 1902
JUNIOR.	
ROBINSON, ARTHUR WIRT	Feb. 4, 1902

DEATHS.

LASSIG, MORITZ.......Elected Member, April 2d, 1884; died Jan. 7th, 1902.

REINHOLDT, KENNETH OAKE PLUMMER..Elected Junior, Feb. 6th, 1894, Associate Member, October 7th, 1896; died Feb. 6th, 1902.

RUSSELL, NATHANIEL EDWARDS.......Elected Member Oct. 3d, 1888; died Jan. 14th, 1902.

VAN SLOOTEN, WILLIAM .... Elected Member, Nov. 3d, 1897; died Dec. 14th, 1901.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(January 8th to February 11th, 1902.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Eng., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Can.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Institute, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 30c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 35c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England.
(22) *Iron and Coal Trades Review*, London, England.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, 75c.
(29) *Journal*, Society of Arts, London, England.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des Ecôle Spéciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Eng., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 75c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 10c.
(47) *Mechanical Engineer*, Manchester, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Institute of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 10c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.

Bridge.

Summer Street Viaduct, South Boston.* Herman K. Higgins. (1) Dec.
A Three-Hinged Concrete Arch Bridge over the Danube at Ehingen.* (13) Jan. 9.
The Condition of the Brooklyn Bridge. (15) Jan. 10.
The Railway Bridge over the Godavari River at Rajahmundry, on the East Coast Railway, India.* (11) Jan. 10.
The Erection of the Portage du Fort Bridge.* (14) Jan. 11.
A New Scherzer Rolling Lift Bridge at Cleveland.* (15) Jan. 17; (18) Jan. 18.
Erection of Girder Spans on the West Virginia Short Line R. R.* (14) Jan. 18.
Arched Viaduct over the Seine, Paris. (11) Jan. 31.
An Eventful Bridge History (Johnsonville, Tenn.). Hunter M'Donald. (15) Feb. 7.
Reinforcing an Undermined Bridge Pier. (14) Feb. 8.
Note sur le "Pyrmont Bridge," à Sydney.* Ad. Guillemin. (30) Dec.
Le nouveau pont de Luxembourg.* A. Dutreux. (33) Jan. 18.

Electrical.

The Induction Motor and the Rotary Converter and Their Relation to the Transmission System. Chas. F. Scott. (42) Dec.
The Control of High Potential Systems of Large Power.* E. W. Rice, Jr. (42) Dec.
Street Illumination and Units of Light.* W. D'A. Ryan. (42) Dec.
The Incandescent Lamp of To-day. John W. Howell. (42) Dec.
A Note on an Acetylene-in-Oxygen Flame.* Clayton H. Sharp. (42) Dec.
Electric Gas Lamps and Gas Electrical Resistance Phenomena. Peter Cooper Hewitt. (42) Dec.
The Central Exchange of the London Post Office Telephones.* (26) Serial beginning Dec. 6, ending Jan. 3.
Three-Phase Distribution for Power and Lighting.* Sydney Woodfield. (26) Jan. 3.
The Waterside Station of the New York Edison Company.* (27) Serial beginning Jan. 4, ending Feb. 1.
Aluminium: Its Properties and Use. W. Murray Morrison. (47) Jan. 4.
Sparkless Commutation with Fixed Brushes.* Claude W. Hill. (26) Jan. 10.
Applications and Uses of Arc Lamps.* (26) Serial beginning Jan. 10, ending Jan. 17.
Complete Commercial Test of Polyphase Induction Motors Using One Wattmeter and One Voltmeter.* A. S. McAllister. (27) Jan. 11.
Methods of Eliminating Corrections for the Leads, etc., in Cable Testing.* H. Savage. (26) Serial beginning Jan. 17, ending Jan. 24.
The Corbin Process and Cell for the Electrolytic Production of Chlorates.* John B. C. Kershaw. (26) Jan. 17.
The Manufactures of Royce, Limited.* (26) Jan. 17.
Some Experiments with Wireless Telegraphy.* (46) Jan. 18.
Large Generators for Bolton.* (26) Jan. 24.
Dynamo-Testing at the English Electric Manufacturing Company's Works, Preston.* (11) Jan. 24.
Electrical Machinery in the Power Station and Substations of the Manhattan Ry. Co.* (13) Jan. 30.
Electric Appliances in Ship-Building Yards.* Sydney F. Walker. (9) Feb.
The Economy of Isolated Electric Plants.* Isaac D. Parsons. (9) Feb.
Dangers from Electric Trolley Wires and Other Aerial Conductors; How They are Guarded Against in Great Britain.* Andrew Jamieson, M. Inst. C. E. (10) Feb.
The New Central Station of The Citizens' Light and Power Co., Rochester, N. Y.* (64) Feb.
The New Power Plant of the Citizens' Company of Rochester, N. Y.* (27) Feb. 1.
The Electric Light and Power Plant of the New United States Mint, Philadelphia.* Clayton W. Pike. (27) Feb. 1.
Electric Equipment of Railway Docks, Middlesborough, England.* (27) Feb. 1.
The Electric Installation of the Natural Food Factory at Niagara Falls, N. Y.* Arthur B. Weeks. (27) Feb. 8.
Omnibus automobile électrique de la Compagnie de Traction par trolley automoteur.* (34) Jan.

Marine.

German Cruiser *König Wilhelm Ersatz.** (12) Dec. 27.
A New Dry Dock at Baltimore, Md.* (13) Jan. 9.
The Japanese Battleship *Mikasa.** (12) Jan. 10.
New Japanese Cruisers *Niitaka* and *Tsushima.* (12) Jan. 24.
Tubes with Sides and without, in Ship Resistance; An Example from Lord Kelvin.* Marston Niles. (19) Feb. 1.
Contribution à la Recherche de l'Insubmersibilité des Grands Navires d'Acier.* E. Duchesne. (32) Nov.
La Perte du Contre-Torpilleur Anglais *Cobra.* (33) Dec. 28.

Mechanical.

English, American and Continental Steam Engineering.* Philip Dawson. (9) Serial beginning Nov., ending Feb.
The Present Status of the Question of a Standard of Light. Clayton H. Sharp. (42) Dec.

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* Illustrated.

Mechanical—(Continued).

Smoke Abatement in St. Louis.* William H. Bryan. (1) Dec.
The Efficiency of Compound Centrifugal Pumps.* F. G. Hesse. (1) Dec.
On the Speed of Machine-Shop Tools. J. W. E. Littledale. (11) Dec. 27.
English and French Practice in the Manufacture of Cast-Iron Pipes. Stephen H. Terry, M. Inst. C. E., and A. G. Cloake. (47) Dec. 28.
Comparison of Cost of Operating an Iron Smelting Plant by Gas Engines Using Waste Blast Furnace Gas, and by Gas Fired Boilers and Steam Engines. William M. Chatard, Henry J. Botchford, and Emley M. Holcombe. (8) Jan.
Machinery at the St. Louis Exposition.* (41) Jan.
Thermal Emissivity in High-Pressure Gases.* (11) Jan. 3.
The De Laval Steam Turbine.* (20) Jan. 9.
Report of the Committee on Standard Pipe Unions of the American Society of Mechanical Engineers.* (20) Jan. 9.
Bickford's New Radial Drill.* (62) Jan. 9.
French Spirit Motors. (11) Jan. 10.
A Silent Chain Gear.* J. O. Nixon. (19) Jan. 11.
Gas from Oil: Process as Conducted on the Pacific Coast.* (24) Jan. 13.
A New Crank Pin Turning Machine.* (20) Jan. 16.
Modern Plants for the Manufacture of Hoops and Merchant Bars.* Theo. J. Vollkommer. (20) Jan. 16.
The Design and Construction of Flywheels for Slow-Speed Engines for Electric Lighting and Traction Purposes.* A. Marshall Downie. (11) Serial beginning Jan. 17, ending Jan. 24.
Acetylene for Gas Engines. (12) Jan. 17.
High-Speed Steam Engines. John Davidson. (12) Serial beginning Jan. 3, ending Jan. 17.
Combustion in Gas Producers and Benches. Robert W. Prosser. (24) Serial beginning Jan. 20, ending Jan. 27.
A New Machine for Ore Unloading.* (20) Jan. 23.
The Sellers 28-Foot Boring and Turning Mill.* (20) Jan. 23.
The Lindsay Reversing Gear for Rolling Mills.* (20) Jan. 23.
Modern Machine Methods.* H. F. L. Orcutt. (Paper read before the Institution of Mechanical Engineers.) (11) also (12) Serial beginning Jan. 24, ending Jan. 31.
A Successful Bag-Conveying System.* (13) Jan. 30.
Comparative Tests of Coal and Crude Oil as Fuel.* (13) Jan. 30.
The Bureau of Printing and Engraving.* Waldon Fawcett. (62) Jan. 30.
Hoisting Machinery.* Joseph Horner. (10) Feb.
American Traction Engine Notes.* Charles O. Heggem. (10) Feb.
Fuel Value of Texas Oil.* J. E. Denton. (64) Feb.
Feed Water Heaters in Condensing Plants. C. G. Robbins. (64) Feb.
Lessons from the Automobile Endurance Contest. R. H. Thurston. (19) Feb. 1.
Power Plant of the Booth Cold Storage Warehouse, Chicago.* (14) Feb. 1.
Machine Tools in Ship Yards.* Waldon Fawcett. (41) Feb. 1.
Steam Turbines.* F. J. Warburton. (47) Feb. 1.
Tests of Beaumont Oil as Fuel.* (16) Feb. 1.
Gas Distribution at Leeds, England.* (Abstract from the *Gas World.*) (24) Feb. 3.
Gas and Gasoline Engine Ignition. Albert Stritmatter. (62) Feb. 6.
The Cambria Steel Company's New Works.* (20) Feb. 6.
Natural Gas and Other Fuels—A Comparison.* (15) Feb. 7.
The Bursting of Small Cast-Iron Fly-Wheels.* Charles H. Benjamin. (19) Feb. 8.
Rope Transmission of Power. E. C. DeWolfe. (Extract from paper read before Indiana Eng. Soc.) (14) Feb. 8.
Metallic Joints for Steam, Air and Water: Also Quick-Opening Valve Suitable for Gas Works, etc.* (24) Feb. 10.
Concours Général des Moteurs et Automobiles à Alcool. M. Ringelmann. (32) Dec.
Les Progrès de la Navigation Aérienne et les Expériences de M. Santos-Dumont. M. Armengaud, Jeune. (32) Dec.
Machine Compound demi-fixe, à vapeur surchauffée, système. R. Wolf. (34) Jan.

Metallurgical.

Crucible Steel: Its Manufacture and Treatment. David Flather. (22) Serial beginning Dec. 20, ending Dec. 27.
Concentration Practice in Southeast Missouri.* R. B. Brinsmade. (45) Jan.
The Microscopical Examination of the Alloys of Copper and Tin.* William Campbell. (11) Serial beginning Jan. 3, ending Jan. 17.
A Modern Foundry; a Good Example of Design and Equipment.* Albert L. Rohrer. (10) Feb.
Lead Smelting in Southeast Missouri.* R. B. Brinsmade. (45) Feb.

Military.

Repairing Worn-Out Guns on Service.* Colonel R. Bannatine-Allason. (12) Jan. 10.

Mining.

Mining Operations in Atlin, B. C.: A Description of Some of the Placers and Hydraulic Plants which are being Installed.* R. Lind Watson. (45) Serial beginning Dec., ending Jan.

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* Illustrated.

Mining—(Continued).

Electric Mine Haulage.* W. B. Clarke. (45) Jan.
Western Australia's Mining Industries.* H. L. Geissel. (16) Jan. 4.
The Eisenbeis Pick Mining Machine. (22) Jan. 10.
A Mine-Pumping Plant with Electrically-Driven Centrifugal Pumps.* (13) Jan. 23.
Opportunities for Improvement in Mica Mining. George W. Colles. (9) Feb.
New Plant at Shaft No. 5 of the Spring Valley Coal Co., at Spring Valley, Ill.* A. Dinsmoor. (45) Feb.
Mechanical Engineering, as Applied to Coal Mines, and Its Relation to the Economical and Successful Operation of the Same.* Wm. Glyde Wilkins. (Paper read before Western Penn. Central Min. Inst.) (45) Feb.
White Horse Mining District, Yukon Territory.* William M. Brewer. (16) Feb. 1.
The Mining District of Guanajuato, Mexico.* (16) Feb. 8.

Miscellaneous.

Engineering and Industrial Enterprises at Sault Ste. Marie.* (13) Jan. 9.

Municipal.

Making Roads by Machinery.* Waldon Fawcett. (46) Jan. 11.
The State Roads of Massachusetts. Albert S. Merrill. (14) Jan. 11.
Bituminous Macadam Pavement. (14) Jan. 25.
Proposed Changes in the New York Asphalt Paving Specifications. (13) Feb. 6.
Criticisms of the New York Asphalt Pavement Specifications. A. W. Dow. (13) Feb. 6.
Some Economic Features in Municipal Engineering. C. S. Burns, Assoc. M. Am. Soc. C. E. (14) Feb. 8.

Railroad.

Locomotive Rating—Adjusted Tonnage Method.* D. F. Crawford. (61) Dec. 17.
The Trans-Australian Railway Scheme. Stafford Ransome, M. Inst. C. E. (12) Dec. 27.
The "Reid" 10-Coupled Tank Engines: Natal Government Railways.* (21) Jan.
The Building of a Modern Locomotive.* (19) Serial beginning Jan. 4, ending Jan. 11.
Bogie Express Passenger Engine for the South Eastern and Chatham Railway.* (47) Jan. 4.
Wide Firebox Atlantic Type Locomotive.* (40) Jan. 10.
Central of Georgia Box Cars.* (40) Jan. 10.
The Proper Utilization of Motive Power. (15) Jan. 10.
Lignite-Burning Consolidation Locomotive—Bismarck, Washburn & Great Falls.* (15) Jan. 10.
Four-Cylinder Tandem Compound Decapod Locomotive—Largest Engine Yet Built.* (18) Jan. 11.
A New Method of Building Embankments.* (13) Jan. 16.
Interlocking and Signal Work on the Union Pacific.* (40) Jan. 17.
The Investigation of the Park Avenue Tunnel Disaster. (13) Jan. 23.
Six-Coupled Express Locomotive. Eastern Railway of France.* (12) Jan. 24.
The New York Central Accident—Electricity—Protection by Signals.* S. S. Neff. (15) Jan. 24.
Some Factors Affecting the Power of Locomotives.* (15) Jan. 24.
Oil Burning Locomotives on the Southern Pacific.* (15) Jan. 24.
Passenger Mogul for the New York, Ontario and Western.* (40) Jan. 24.
Comments on the Electrical Equipment of the New York Central Tunnel. (17) Jan. 25.
Proposed Solution of the New York Central Terminal Problem.* (26) Jan. 25.
The Langen Suspended Railway of Barmen-Vohwinkel-Elberfeld.* Prof. Dolezalek. (46) Jan. 25.
Investigation of the Park Ave. Tunnel Collision. (13) Jan. 30.
Flexibility in Car Coupling Attachments.* (13) Jan. 30.
New York Central Underground Passenger Loop.* (40) Jan. 31.
Tandem Compound Decapod for the Santa Fé.* (40) Jan. 31.
New Construction of Steel Center Sills and Bolsters; Chicago, Milwaukee and St. Paul Railway.* (25) Feb.
The Nilgiri Mountain Railway; the First Abt Rack Railway in India.* Walter James Weightman, M. Inst. C. E. (10) Feb.
Decapod Tandem Compound Locomotive; Atchison, Topeka and Santa Fé Railway.* (25) Feb.
Box Car, 80 000 Pounds Capacity; Chesapeake and Ohio Railway.* (25) Feb.
New Locomotive Shops; Central Railroad of New Jersey, at Elizabethport, N. J.* (25) Feb.
Compound Consolidation Passenger Locomotive; Colorado Midland Railway. (25) Feb.
Chautauqua Type Locomotive, Central Railroad of New Jersey.* (39) Feb.
Track Elevation on the New York, New Haven and Hartford R. R. at Boston, Mass.* (18) Feb. 1.
Construction Work on the Aurora, Elgin and Chicago Railway.* (17) Feb. 1.
Steam Motor Cars for Railway Service.* (13) Feb. 6.
A New Device for Displaying Train Order Signals.* (40) Feb. 7.
Concrete Structures for Railways. W. A. Rogers, M. Am. Soc. C. E. (Abstract of paper presented to the Ill. Soc. of Engrs. and Surveyors.) (14) Feb. 8.
High-Speed German Railway at Zossen.* Frank C. Perkins. (46) Feb. 8.
The Proper Utilization of Motive Power.* (18) Feb. 8.

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* Illustrated.

Railroad—(Continued).

Train Order Locking Device on Block Signals.* (18) Feb. 8.
60 000-lbs. Capacity Stock Car, Illinois Central R. R.* (18) Feb. 8.
Les Chemins de Fer aux Indes Néerlandaises (Java et Sumatra). Auguste Moreau. (32) Dec.
La Construction des Locomotives aux États-Unis.* (36) Dec. 25.
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Vol. XXVIII. FEBRUARY, 1902. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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CONTENTS.

Acme Summit, at the base of Mt. Shasta, are important entrances into the great valley. The Sacramento and San Joaquin Rivers, and their tributaries, water and drain the valley; their combined water-sheds embrace an area of 58 100 sq. miles, situated principally upon the western slope of the Sierra Nevada and the eastern slope of the Coast Range. The edges of this water-shed are the crests of the two ranges of mountains, except an area extending into Oregon in the drainage basin of Goose Lake, which lake when full drains into Pitt River, one of the main tributaries of the Sacramento. The eastern crest rises from 6 800 to 15 000 ft., and the western crest rises from a single tide-level gap at Carquinez Straits to elevations of 900 to 9 000 ft. The gaps in these mountain ranges, and the ridge and valley lines subdividing and lying between them, constitute controlling features in the development of a road system.

Climate.

In variety of climate, the area under consideration presents a wider range than do both the comparative areas just described. Besides the climatic variations, due to difference of latitude or distance from the sea, California presents a wide range of temperature, due to differences in elevation. These differences extend from the arctic temperatures of 15 000 ft. above, to the semi-torrid climate of areas 400 ft. below, sea level. Between these extremes every grade of temperature and exposure exists. In the hotter portions, fruits and vegetables grow without intermission during the entire year; while upon the colder heights frosts form in midsummer, and only the hardiest boreal plant life exists. Severe frosts and freezing are limited to the most elevated parts of the state. In the greater portion of the higher mountains snow falls before severe freezing weather occurs, and remains until the warm weather of spring, thus protecting from frost action the road-beds in these regions; and hence no great precautions are necessary to resist its injurious action upon roads.

Rainfall.

California occupies a position between the north temperate and the equatorial rain belts. The northern part of the state is just within reach of the summer rains of the north temperature rain belt; and the mountains of the extreme southern part of the state are frequently

SKETCH MAP, SHOWING THE RELATIVE SIZE AND LATITUDE OF CALIFORNIA COMPARED WITH THE EAST COAST OF THE UNITED STATES.

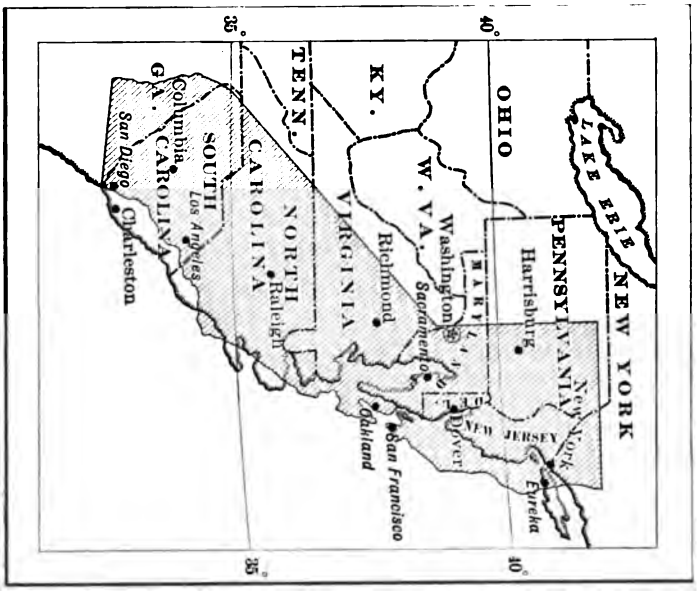

Fig. 1.

SKETCH MAP, SHOWING THE RELATIVE SIZE AND LATITUDE OF CALIFORNIA COMPARED WITH THE WEST COAST OF EUROPE AND AFRICA.

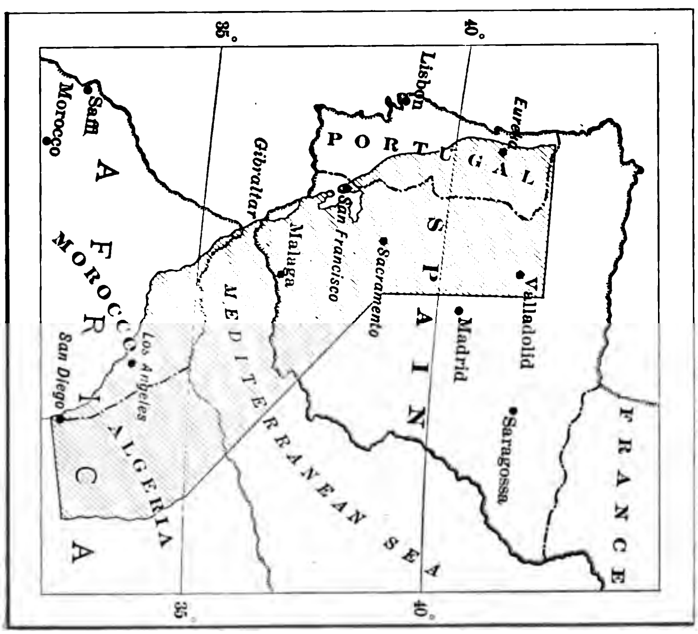

Fig. 2.

reached by the "Sonora rains," which extend in summer over Northern Mexico and into Arizona, and which originate in the equatorial rain belt. The winter rains of the entire state are principally dependent upon the southern extension of the north temperate rain belt as that hemisphere is turned away from solar energy. Therefore the state has winter rains, and enjoys a comparatively rainless summer.

The mean annual precipitation in the northwestern part of the state and upon the exposed flanks of the Sierras and Coast Range is 70 to 80 ins.; while in the southeastern portion of the state there are comparatively rainless areas, receiving from 2 to 4 ins. annually. Between these two extremes, again, there lies every degree of annual moisture. This precipitation, however, is rarely so heavy that a properly located, well-surfaced, and well-drained roadbed will be badly washed.

Vegetation.

The distribution and variety of vegetation over an area of such extreme range of climatic and moisture conditions are also of wide range, both in species and density. The forest growth is sometimes so dense that over 1 000 000 ft. of lumber can be cut from a single acre, but in the drier portions of the state it is difficult or impossible to get shade trees to grow, and other areas are absolutely devoid of vegetation. In the densely timbered areas clearing and grubbing are expensive, and the shading of the roadway causes it to remain wet longer than is desirable.

Natural Resources.

Besides these physical features which have to be considered, there are four belts of natural resources which have controlled the time, locus, and mode of development of certain industries. These directly influence a road system, and determine controlling points of population and trade.

In progression eastwardly, and in order of development, these are

First.—The mineral belt, commencing in Del Norte County, and reaching southeastwardly through the entire limits of the state;

Second.—The agricultural belt of 16 000 sq. miles of fertile land, in the Valley of California;

Third.—The timber belt, commencing in the northwesterly corner of the state, and extending southeastwardly to the Golden Gate;

Fourth.—The fruit belt, commencing at the base of Mt. St. Helena, and extending southerly to the national boundary.

Each of these belts is interspersed with sources of wealth other than those which characterize it; as, for instance, the Sierra timber belt which lies east of and along the mineral deposits on the flanks of the Sierras, and the foot-hill fruit belt at their base. The foregoing classification, however, marks the predominant natural wealth of each of the various sections.

At advantageous points along each of these belts, centers of population are growing up. The problem of laying out the lines of communication which must for all time control the travel and traffic of the state, therefore, must be subservient to two great controlling factors: First, these roads must lie along those lines, determined by Nature, which offer the best grades and alignments; second, they must subserve the economic purposes demanded in the development of the state.

Occurrence of Road-Building Materials.

The Department of Highways extended the work of investigating the various materials suitable for road surfacing, and these investigations showed that there is an abundance of materials over the entire state which can be utilized with great benefit to economic road maintenance. In almost every county adequate materials exist, which, if utilized with skill and judgment, will make good metal. The failures to utilize these materials have been due in part to a lack of knowledge as to their character, and of technical skill as to the mode of using them.

All hard, silicious rocks, such as chert, jasper, quartz, quartzite, etc., the volcanic rocks (trap and basalt), and a wide series of metamorphic rocks occur abundantly. In addition, bowlders, cobbles and gravel of miscellaneous composition, but exceedingly hard and durable, are scattered over great areas. Hard limestone and some of the silicious shales occur in many counties. Occurring with these rocks are others which are inferior or useless for road-surfacing. Many instances of failure in the use of rock have been due to the selection of the wrong material. Again, the proper selection has been made, but the materials have not been properly utilized. The best rock roughly cracked up and dumped over a road will no more make a road surface than shingles dumped on a shed and scattered with a rake will make a roof.

The best rock must be selected, properly crushed and screened, and then spread, sprinkled, and rolled in layers over a well-graded and drained surface. In one county, an excellent binding material, a soft limestone, was found. It was being hauled a considerable distance, and used almost alongside of the hardest and most durable chert, with which a small proportion of the limestone should have been used as a binding or cementing material. This would have given a better and more durable road surface and saved the long haul from the limestone quarry of nine-tenths of the stone used.

Legal Considerations.

In addition to the physical conditions, there are others imposed by the administration of the law in the various political divisions of the state. The state is divided into fifty-seven counties, which range in area from the 20 000 sq. miles of San Bernardino County to the 43 sq. miles of San Francisco County; and in taxable wealth from the $400 000 000 of this latter county to the $260 000 of Alpine County. Furthermore, these counties are divided by law into fifty-three "classes," in each of which material variations are presented in the number, compensation and duties of county officers.

The entire matter of road-building and maintenance has been in the hands of the Boards of Supervisors of these counties, or in the charge of Road Overseers, elected in the road districts into which the counties were subdivided. The abuses incident to the latter control were so great that the roads were placed under the control of the Boards of Supervisors, each member being made Road Commissioner of his district. The control of road funds under Road Overseers became so vital a matter in local politics that at elections the votes for Presidential Elector were sometimes "swapped" for those for Road Overseer.

The laws under which the county officers administer road affairs have been so modified, amended and added to, in the past forty or more years, that they are contradictory and inapplicable. Amendments made to correct difficulties, abuses or even physical conditions, in one portion of the state have made "confusion worse confounded" in other portions. Hence, the exact provisions of the code were not only unascertainable, but in many instances inapplicable, and, furthermore, subject to different interpretations by different officials.

The obstacles to be dealt with are therefore of two classes: (1) physical; (2) political.

Of these, the first can be met by the engineer in almost any form, provided the necessities for overcoming them warrant the raising of the required funds.

The second class, or political obstacles, are so entrenched by custom and control that only long devotion to civic duty by a majority of the voters of a county or state can correct them, and the attack cannot be made successfully until justified by the state of public opinion.

The system of placing county road matters in the hands of a Board of Supervisors, not one of whom is trained for the work, is radically wrong. It happens frequently that members of these boards are faithful, energetic men, who are devoted to the duties of the office, and discharge their obligations to the public with honest efficiency. Many instances of this kind were met by the writer in various parts of the state.

The works of these officials might be considered models, when the obstacles and difficulties under which they were executed were considered. But, unfortunately, this was not the rule. In the majority of instances road moneys were regarded as the funds from which to pay political debts and obligations, or were to be called upon just before elections for the purpose of putting an army of "workers" on the roads where they "would do the most good," not to the roads, but to some candidate.

This absurd and obscure condition of the law and its administration can be understood only when the actual conditions of road management in the entire country, previous to and during that period of its history in which California has developed, are considered; and, without the consideration of these conditions, road mismanagement by an intelligent people is inexplicable. Hence it becomes necessary to review very briefly the modes of road development in the United States since the advent of the railroad.

Historical Notes.

In the early part of the century, the prosperity and development succeeding the War of the Revolution required ample and extended means of communication. The common roads of the

country were supplemented by toll roads, which were built by companies, on franchises granted for variable periods. These toll roads were frequently built of plank, but were generally of earth and gravel.

The exaction of toll upon these roads became burdensome and restrictive of development; consequently, the acquisition of many of them became a public necessity. From that date to the present we have had it impressed upon us that whenever those utilities which the people should provide and control for themselves have been farmed out to corporations, oppression has resulted—no matter whether the farmed-out franchises were a toll road from Pittsburg to Philadelphia, or a transcontinental railroad to the Pacific Ocean.

The necessities for cheap transportation became so great that the United States Congress, cabinet officers, the President—in fact, almost all the functions of the National, State and County Governments were engaged in the study and practical application of the science of road building. Reports of cabinet officers, messages of the Presidents, and the views of the leading statesmen of our country, bearing on this subject, are very common in Government documents during the early decades of the nineteenth century. Notable among these are:

1.—The Act admitting Ohio, in 1802, and setting apart 5% of the sales of public lands as a road construction fund. These sales netted something over $750 000 in a few years.

2.—The bill introduced by Mr. Tracy, of Connecticut, and approved in 1806 by President Jefferson. The debates on this Act show how deeply the road question interested the country.

3.—The speech of Mr. Calhoun in favor of placing the bonus on all bonds sold, and dividends of the national banks, in a fund for the construction of roads and canals; this fund would have amounted to nearly $750 000 annually. This bill, however, was vetoed by President Monroe, in 1817, on the ground that it was unconstitutional, even if the States gave their consent to the provisions of the law.

An extensive system of roads was projected and partly constructed by Congress. The most noted were the "National Turnpikes" in Maryland, Virginia, Pennsylvania and Ohio, which aggregated several

hundred miles in length, and received Congressional appropriations amounting to $7 000 000 in annual appropriations of from $30 000 to $500 000.

Finally, in 1834–35, an appropriation of $300 000 was made for repairing the National roads in Pennsylvania, Maryland and Virginia, and when repaired they were transferred to these states.

Just as road building, fostered by our government and placed in the hands of skillful engineers, became a science, the invention of the locomotive and the consequent development of railroad building came about. At once, all the energies of our people were centered upon this new mode of transportation. So great was the impetus thus given, that the United States soon ran far ahead of other countries in mileage of railroad. For generations the building of roads was forgotten, and the building of railroads stimulated and fostered. The highest skill of the trained engineers of the country has been and is engaged in the general and special work of building, equipping and operating railroads.

During this period of railroad growth and development, roads have been neglected to such an extent that generations have grown up who have never seen a road. They have learned to speak of streaks of dust or mud, as the case may be, as roads—have actually learned to regard them as such, and solemnly dedicate the same to public use, with all due legal form, as if they really were well-located, graded, drained and thoroughly metaled highways. The engineers of the country have so seldom, until lately, been engaged on roadwork that they, too, have looked upon road building as a lost art which at one time was practiced by the ancients.

Under these conditions California was settled, and her laws for road location, construction and management, were framed and developed during a period when road building was at its lowest ebb.

The road system of California, therefore, grew up during a period of general road decadence throughout the entire United States. It has also had a makeshift system grafted upon it from the start. The energies which led the pioneers to traverse a continent in the search for gold was coupled with a love of home which limited their contemplated stay in California to the shortest possible period consistent with the acquirement of wealth. They were, therefore, content with trails, roads and bridges which were essentially temporary or make-

shift in character. Consequently, Californians have learned to regard road building and maintenance as the result of temporary expedients resorted to only when forced by necessity. In some instances, where wise forethought has prompted permanent work and materials, the step has been regarded as an expensive "experiment," and the officials inaugurating these improvements have been accused of extravagance.

It is, therefore, not so much a matter of surprise that the condition of affairs mentioned in the earlier part of this paper grew up along such systemless and extravagant lines.

But the expense of operating bad roads forced a consideration of the methods necessary for correct road location, construction and maintenance. The state had in 1895 reached the limit of development possible under bad roads, and further development was and is yet dependent upon the systematic construction of highways of the most approved type.

Under these necessities, the law of 1895, previously mentioned, was passed.

LEGISLATION.

After two years spent in investigating the subject and in examining the conditions thoughout the state, the Commissioners of the Bureau of Highways recommended minor changes in the then existing laws—principally to harmonize them—and four general laws. These were:

(1)—An Act to classify the roads of the State into (*a*) State Highways; (*b*) County Thoroughfares; (*c*) District Roads.

(2)—An Act empowering the State to gradually take charge of, construct and maintain highways of the first class, and making provision therefor, by the levy of a tax of 2½ cents on the $100 of assessed valuation.

(3)—An Act regulating the width of tires.

(4)—An Act creating a Department of Highways.

(5)—An Amendment reducing the maximum rate of road taxation from 40 to 35 cents per $100 of assessed valuation.

The objects and principles of these laws had been announced and discussed, during the year preceding their introduction, in every county seat and important town, and had met with the general approval of the citizens and the press. Each of the political parties

had put a "plank" in its "platform," looking to the betterment of road conditions, which was supposed to pledge the members of the Legislature to remedial measures.

Of these proposed acts, only one—that regulating the width of tires—became a law. This was drawn to go into effect in 1900. It met with the disapproval of the dealers in and manufacturers of wagons, and at the extra session in 1899–1900 was rendered inoperative.

The law classifying roads was radically changed by the introduction of clauses which would permit of making unimportant roads State Highways, when they could never form the essential parts or links of a great highway system, and would, furthermore, place no limit on the mileage of such additions to the State's obligation. Recognizing the evils of these changes, the Executive withheld his signature.

The bill providing for State construction and maintenance of highways of the first class was amended to entirely alter its purport, and was vetoed by the Governor.

The recommendation to levy 2½ cents on the $100, for the construction of State Highways, was also radically changed by extracting essential features and incorporating them in another bill, practically placing 85% of that levy to the credit of the counties, to be expended under and by county authorities; also, providing that state officials should indorse bonds issued by the counties, and, in default of the counties paying the interest thereon, that the State should collect and pay such interest. These provisions were contrary to the plain provisions of Article IV, Section 31, of the Constitution, which prohibits the granting of the money or credit of the State to political or other corporations or to persons. These measures failed to become laws, as did the bill previously mentioned.

The bill creating the Department of Highways was amended, for partisan purposes, so as to give patronage in State elections.

The recommendation to reduce the maximum rate of taxation for road purposes from 40 to 35 cents per $100 was not considered by the Legislature, and, instead of a reduction, the maximum was raised to 62½ cents per $100 of assessed valuation, by the addition of certain district levies.

An act, constituting Chapter CCLIXIV of the Statutes and Amendments to the Code, 1897, was introduced as an "urgent necessity," and

passed during the last eighteen hours of the session. It was known as the "Clark Road Law." It was never printed or submitted to consideration, and its existence was kept secret from the members of the Bureau of Highways. This law subsequently came before the Supreme Court,* and was declared illegal.

An act intended to provide a connecting link between the roads on either side of the Sierras and between the Yosemite Valley and the basin of Mono Lake was also passed, but, the title being defective, it failed to receive the signature of the Governor.

The Legislature of 1897 also made a conditional appropriation of dimension stone for sub-structures and of crushed rock for macadamizing the road from Sacramento to Folsom, a distance of about 20 miles. Near this latter point one of the state penitentiaries is situated, and convict labor was to quarry, dress, or crush the rock. The condition of this appropriation of materials was that the county should provide the funds necessary to grade the roadbed, distribute and roll the crushed rock, etc.

This road was to be a model for the state and county officers, who meet biennially at the Capitol.

The work was placed in the hands of a non-technical commission. The members of the Department of Highways undertook to present the matter to the county officials and the people of the county for a bond election. This election resulted very favorably, but the legal provisions and steps were not fully in accordance with the law, and the courts declared the bond issue invalid.

This, in brief, is the history of the first two years' attempt to institute system and economy in road work in California.

The work, however, was continued through a Department of Highways, which took the place of the previous Bureau, and for two years consisted of three members, and thereafter of one member, who was to be appointed for four years.

The Department of Highways thus created continued the work provided for by law, but, by lack of funds, was not permitted to execute any important road work. The members acted in an advisory capacity to County Boards of Supervisors and to County Surveyors. In a few instances opportunities were found to practically advance road building.

* In Davis vs. Whidden, 117 Cal., 618.

In laying out a system of highways it must be recognized that there are two main principles to be followed. First: The main highways of the state and its counties are lines along which the travel and traffic of an indefinite future must move, and it is therefore necessary to locate these lines on the most advantageous ground, irrespective of temporary private interests, which at most can last for only one or two generations. After roads have been located upon these lines no false economy or makeshift methods should be allowed; the drains, culverts and bridges should be of masonry, the roadbed graded to true lines, and a sprinkling plant provided. Finally, the surface should be metaled with the best available rock. To attempt this upon all roads, with the entire road fund of each county, is not practicable. Existing roads, however bad, must be maintained so as to permit of reasonable use, even if this use temporarily entails heavy loss.

The second principle is that true economy shall characterize the expenditure of available funds. The existing roads must be kept in that state of repair which will enable them to meet the requirements of travel and transportation, and, in addition, a gradual change to proper locations, and the substitution of permanent structures for makeshift and perishable ones, must be made.

It was, therefore, recommended that one-half of the road funds of each county be set aside as a "Good Roads Fund," to be used as the necessities of the county might dictate. It is entirely possible with the remaining half of the road funds to maintain existing roads in as good condition as they have been for some years past. Particularly is this possible, if wasteful methods and political favoritism be set aside, and system and economy instituted. Should this measure reduce the funds below the requirements of special local interests, the Board of Supervisors has it in its power to levy for this purpose the special tax provided in Section 38, Chapter CCLXXVII of the Statutes and Amendments of 1897. The setting aside of a portion of these funds for permanent work was intended as a means of bringing about system and economy. This, however, cannot be accomplished by law alone. It is imperatively necessary that there should be integrity, technical intelligence, and energy on the part of the officials charged with the disbursement of road funds.

The construction and maintenance of bridges was found to be particularly costly in all except two counties. In one the cost had been

reduced by placing the entire matter of bridge building in the hands of the County Surveyor, an engineer of high skill and integrity. In the other it was realized that masonry was far cheaper than steel, iron and wood. The results of these two examples were freely used by the Highway Commissioners, and the lessons were not wholly lost.

FIG. 8.

The prime reasons why bridge building and maintenance are so costly are: First, in many instances the bridges are expensive because the county officials do not know the actual cost of materials and labor; and, secondly, a lack of technical knowledge in the matter permits the use of the wrong materials.

Bridges, which should be masonry, are built of very perishable timber, the constant renewals of which exhaust the road funds.

The raising of about $2 000 000 per year for highway purposes is equivalent to a tax levy of 20 cents per $100 on $1 000 000 000. This amounts to $80 000 000 in forty years, which sum, intelligently and honestly expended would give California a magnificent system of highways; but it requires the introduction of system, skill, and integrity in every detail, and, if the present system be continued, the full benefit of the expenditure of this vast sum will fall short of being realized.

At the next session of the Legislature, in January, 1899, the Department of Highways renewed the recommendations previously made, and added an important amendment, looking to the creation of a good roads fund in every county, but leaving its control under county authorities. This control is, as previously outlined, considered a very essential part of the political patronage of members of the several Boards of Supervisors, and they generally regard any attempt to put road matters on better lines as an interference with their prerogatives and rights. This amendment apportions 50% of all road moneys for the construction of permanent work in a specified order. Considering that the gross annual expenditures by counties aggregate about $2 000 000, this "good roads fund" would, in a few decades of systematic work, accomplish much good.

These laws and amendments are appended herein in full. They are not intended to be radical nor to subvert the method of road administration, but are designed to introduce system and economy, and to gradually correct the abuses and lack of business methods which had grown to be a part of road administration.

An Act to Classify the Roads in the State of California, and to Define each Class.

The People of the State of California, represented by Senate and Assembly, do enact as follows:

Section 1.—The roads within the limits of the State of California shall hereafter be classified as follows:

The first class to include all highways designated as State Highways; the second to include all highways designated as County Thoroughfares; and the third class to include all highways designated as District Roads.

Section 2.—The following roads, when definitely located by the Department of Highways, are hereby declared to belong to the first class.

1. A highway commencing on the State line between the State of California and the State of Oregon, at or near the point where the said State line is intersected by the road from Yreka, California, to Ashland, Oregon, and extending thence southerly, along the best grades and alignments, through the Counties of Siskiyou, Shasta, Tehama, Butte, Yuba, Sutter, Sacramento, San Joaquin, Stanislaus, Merced, Madera, Fresno, Tulare, Los Angeles, Orange and San Diego to Tia Juana, in the last-named county.

2. A highway commencing at Crescent City, in Del Norte County, and extending south and southeasterly, on the best grades and alignments, through the Counties of Del Norte, Humboldt, Mendocino, Sonomo, and Marin, to the City of Sausalito.

3. A highway commencing in the City and County of San Francisco and extending thence southeasterly, on the best grades and alignments, through the Counties of San Mateo, Santa Clara, San Benito, Monterey, San Luis Obispo, Santa Barbara, Ventura and Los Angeles to the City of Los Angeles.

4. A highway commencing at a point upon the State Highway through Tehama County, at or near the station of Tehama, and extending thence southerly, on the best grades and alignments, through the Counties of Tehama, Glenn, Colusa, Yolo and Solano, to the City of Vallejo.

5. A highway commencing at the City of Martinez, and extending thence southerly, on the best grades and alignments, through the Counties of Contra Costa, Alameda, San Joaquin, Stanislaus, Merced, Fresno, Kings and Kern to a point on the State Highway at or near the City of Bakersfield.

6. A highway commencing at a point upon the State Highway through Siskiyou County, near the westerly base of Mount Shasta, and extending thence southerly, on the best grades and alignments, through the Counties of Siskiyou, Shasta, Lassen, Plumas, Sierra, Nevada, Placer, Eldorado, Alpine, Mono, Inyo, and Kern to Indian Wells, in the last-named county.

7. A highway commencing at the City of Arcata, in Humboldt County, and extending thence southeasterly, on the best grades and alignments, through the Counties of Humboldt, Trinity and Tehama, to a point on the State Highway through Tehama County, at or near the City of Red Bluff.

8. A highway commencing at a point on the State Highway through Shasta County, north of the City of Redding, and extending thence northeasterly, on the best grades and alignments, through the Counties of Shasta, Lassen and Modoc, to Fort Bidwell, in the last-named county.

9. A highway commencing at the City of Marysville, and extending thence northerly and northeasterly, on the best grades and alignments, through the Counties of Yuba, Butte, Plumas and Lassen, to Susanville, in the last-named county.

10. A highway commencing at the City of Ukiah, and extending thence southerly, on the best grades and alignments, through the Counties of Mendocino, Lake and Yolo, to the City of Sacramento, thence easterly, through the Counties of Sacramento and Eldorado, to a point on the State line between the State of California and the State of Nevada, at or near its intersection by the Lake Tahoe Wagon Road.

11. A highway commencing at or near the City of Santa Rosa, and extending thence southeasterly, on the best grades and alignments, through the Counties of Sonomo, Napa and Solano, to Suisun City, in the last-named county.

12. A highway commencing at a point on the State Highway running north from Sacramento, and extending thence northeasterly, on the best grades and alignments, through the Counties of Sacramento, Placer, Nevada and Sierra, to a point on the State Highway through Sierra County, near Sierraville, in the last-named county.

13. A highway commencing at the City of Oakland, and extending thence easterly, on the best grades and alignments, through the Counties of Alameda and San Joaquin, to a point on the State Highway through San Joaquin County, south of the City of Stockton.

14. A highway commencing at the City of Oakland, and running thence northerly and easterly, on the best grades and alignments, through the Counties of Alameda and Contra Costa, to the City of Martinez.

15. A highway commencing at Ione, Amador County, and extending thence easterly, on the best grades and alignments, through Amador, Calaveras, Tuolumne and Mariposa Counties, to the county seat of the last-named county.

16. A highway commencing at a point on the State Highway through Santa Clara County, at or near the City of Gilroy, and extending thence northeasterly, on the best grades and alignments, through the Counties of Santa Clara, San Benito, Merced, Mariposa, Tuolumne and Mono, to a point on the State Highway through the last-named county, near Mono Lake.

17. A highway commencing at a point on the State Highway through Santa Clara County, at or near the City of Gilroy, and extending thence northeasterly and easterly, on the best grades and alignments, through the Counties of Santa Clara, San Benito and Fresno, to the City of Fresno.

18. A highway commening at the City of Modesto and extending thence northeasterly, on the best grades and alignments, through the Counties of Stanislaus and Tuolumne, to the City of Sonora.

19. A highway commencing at or near the City of Hollister, and extending thence southeasterly, on the best grades and alignments, through the Counties of San Benito and Fresno to a point on the westerly State Highway through the last-named county, near Huron.

20. A highway commencing at a point on the State Highway through San Luis Obispo County, at or near San Miguel, and extending thence easterly, on the best grades and alignments, through the Counties of San Luis Obispo and Kern, to a point on the westerly State Highway in the last-named county.

21. A highway commencing at Port Hartford, in San Luis Obispo County, and extending thence southeasterly and northeasterly, on the best grades and alignments, through the Counties of San Luis Obispo, Santa Barbara and Kern to Indian Wells, in the last-named county.

22. A highway commencing at the City of Los Angeles and extending thence easterly, on the best grades and alignments, through the Counties of Los Angeles and San Bernardino, to the City of Bernardino; thence southwesterly, on the best grades and alignments, through the Counties of San Bernardino, Riverside and Orange, to the City of Santa Ana, in Orange County.

23. A highway commencing at a point on the State Highway through Shasta County, north of the City of Redding, and extending thence northwesterly, on the best grades and alignments, through the Counties of Shasta and Trinity, to Weaverville, in the last-named county.

24. A highway commencing at Colusa, and extending thence westerly, on the best grades and alignments, through the County of Colusa, to a point on the State Highway through said county.

25. A highway commencing at Markleeville, and extending thence easterly, on the best grades and alignments, to a point on the State Highway through Alpine County.

26. A highway commencing at Mariposa, and extending thence northwesterly, on the best grades and alignments, to a point on the State Highway through Mariposa County.

27. A highway commencing at the City of Visalia and extending thence westerly, on the best grades and alignments, through the Counties of Tulare and Kings, to the City of Hanford, in Kings County.

28. A highway commencing at a point on the State Highway through Alameda County, at or near Niles, and extending thence southerly, on the best grades and alignments, through Alameda and Santa Cruz Counties to the City of San José; thence southwesterly, on the best grades and alignments, through the Counties of Santa Cruz and Santa Clara, to a point on the highway through Santa Cruz, near Watsonville.

29. A highway commencing at the City of Sonoro, and extending thence easterly, on the best grades and alignments, through the Counties of Tuolumne and Mono, to a point on the State Highway in the last-named county.

Section 3.—The roads of the second class, or County Thoroughfares, shall be the most important roads in each county, as set apart and so declared by the Boards of Supervisors of the several counties, in discharging which duty they may call upon the Department of Highways, in writing, for such advice and counsel as said Board of Supervisors may desire.

Section 4.—The roads of the third class, or District Roads, shall embrace all existing county roads now recognized and set apart by law, and not enumerated in Sections 2 and 3 of this Act as State Highways or County Thoroughfares, together with such additional roads as may be laid out, in accordance with the laws of the State of California, by the Boards of Supervisors of the several counties.

Section 5.—All Acts or parts of Acts in conflict with the provisions of this Act are hereby repealed.

Section 6.—This Act shall take effect from and after its passage.

The total mileage of roads in the State is about 45 000. This classification would put about 10%, or 4 500 miles, in the first class, and this mileage would ultimately come under the control of the State, and includes all the roads in which the State may be considered to have a direct interest. The remaining mileage would continue under county supervision and control.

ARTICLE III, SECTION 2643, PAR. 7, POLITICAL CODE, TO BE AMENDED AS FOLLOWS:

Cause the road tax collected each year to be apportioned and kept in separate funds by the County Treasurer, as follows:

Fifty per cent. of all moneys so collected shall be apportioned as now provided by law.

The remaining 50% of taxes so collected shall be apportioned to a fund to be known and designated as the "Good Roads Fund." All money so apportioned to the "Good Roads Fund" must be expended by the Boards of Supervisors of the various counties in the following manner, and for the purposes hereinafter named, and in no other way, and for no other purpose, to wit:

For laying out, grading, sprinkling, graveling or macadamizing the principal highways of the county, and the purchase of all road machinery necessary for the construction of said highways and main-

tenance of same, and the purchase of water rights, and all necessary property to insure a perfect sprinkling system; for the construction of all substructures necessary to a perfect drainage of a highway or road, all of which substructures shall consist of masonry, concrete, salt-glazed sewer pipe, iron or steel; no lumber or perishable material shall be used, except for bridge flooring, when deemed absolutely necessary.

For better guidance of road construction and the expenditure of moneys in the "Good Roads Fund," the following shall be the order of constructing said highways, and the Boards of Supervisors shall observe this order, so far as possible to do:

First.—The laying out of a highway on the best grades and alignments possible.

Second.—The grading and draining of said highways.

Third.—The construction of permanent substructures.

Fourth.—The establishment of a sprinkling plant for said highways.

Fifth.—The graveling or macadamizing of all such highways.

To perform any work or construct any substructures under this section, the Board of Supervisors to make definite surveys of the proposed work, and to prepare plans, profiles and cross-sections thereof, and to submit the same, with estimate of the amount, or amounts, of work to be done, and the probable cost thereof, and with specifications therefor, duly approved by the Department of Highways of the State of California. The said report shall be prepared in triplicate, one copy to be filed in the Surveyor's office, one in the Department of Highways of said State, and the other to be filed with the Clerk of the Board of Supervisors. The Board, upon receipt of such report, must advertise for bids for the performance of the work specified, as provided in this section. All bidders must be offered opportunity to examine such plans and specifications, and said Board shall award the contract to the lowest responsible bidder, and a copy of the plans and specifications so adopted shall be attached to and become a part of the contract; and the person or corporation to whom the contract is awarded shall be required to execute a bond, to be approved by said Board, for the faithful performance of such contract; *provided*, that after the submission of the bids as herein provided, the Board of Supervisors being advised by the County Surveyor that the work can be done for a sum less than the lowest responsible bid, it shall then be the privilege to reject all bids, and to order the work done, or structure built, by day's work under the supervision and control of said Surveyor; *provided, further*, that the Surveyor in such case shall be held personally responsible, under his official bond, to construct the work and furnish material, at a cost not to exceed the amount of the lowest responsible bid received.

The furnishing of all material or machinery for the purpose of this Act shall be done by contract and advertisement for bids in the same manner as far as possible as designated herein for road work.

The Boards of Supervisors shall decide all questions pertaining to this Act by a majority vote of all members of the Board.

The County Surveyor and Department of Highways of the State shall have power to inspect any work or advise as to the efficiency or quality of all materials so purchased by the Board of Supervisors for the purposes of this Act, and upon the written request by the Surveyor and Department of Highways, any failures to comply with the contract or contracts, or any defects in the character of material furnished, shall be remedied by the contractor, and in default thereof, the Board shall have power to deduct the value of such failure or defect from the contract price agreed to be paid the contractor.

The Board of Supervisors must employ the County Surveyor to superintend the work contemplated by this Act, and, provided said Surveyor is not a salaried officer, must allow him fair compensation for such service.

The Board of Supervisors shall have power to make partial payments upon all contracts let by virtue of this Act, not to exceed 75% of the work done when the same shall be certified by the County Surveyor as properly performed.

No contract shall be let in conformity to this Act exceeding the amount of money in the "Good Roads Fund" of any county, or the estimated amount to be paid into said fund during the fiscal year in which said contract is entered into.

SECTION 2651, POLITICAL CODE, AMENDED TO READ AS FOLLOWS:

The Board of Supervisors must annually set apart, from the property road tax collected from all sources, 50%, to be set aside as provided in Article III, Section 2643, Par. 7, Political Code; 35% of the remainder of said road tax may be set aside for general county road purposes; from which sum so set apart they may direct such amounts to be paid as may be found necessary for such general county road purposes in which the inhabitants of all the districts within the county are more or less interested, or to assist weak or impoverished districts in keeping their roads in repair, to be applied as the said Board may order or direct; *provided*, that the Boards of Supervisors in the several counties shall have no power to create a debt on any road district in excess of the estimated amount of receipts from said district for the current fiscal year.

AN ACT TO PROVIDE FOR THE ACCEPTANCE OF HIGHWAYS OF THE FIRST CLASS BY THE STATE, AND THE MAINTENANCE OF THE SAME, AND TO MAKE AN APPROPRIATION THEREFOR.

The People of the State of California, Represented in the Senate and Assembly, do enact as follows:

Section 1.—Whenever five or more consecutive miles of highways of the first class, as defined in an Act entitled "An Act to classify the roads in the State of California, and to define each class," shall have been located and constructed within the limits of any county in conformity with plans and specifications approved by the Department of Highways, the Board of Supervisors of such county may petition the Department of Highways to accept said portion of road and to maintain the same.

Section 2.—Said Department shall thereupon examine said road and certify to the Governor of the State whether or not such location and construction have been in conformity with the plans and specifications therefor, and if in its opinion said roads should be accepted. Should such opinion be favorable, and meet with the approval of the Governor, such road must then be accepted by the Department in the name of the State, and shall thereafter be maintained by the Department of Highways as provided by the law.

Section 3.—An appropriation of $100 000, or so much thereof as may be necessary, is hereby made for the purposes of carrying out the provisions of this Act during the fiscal years of 1899–1900 and 1900–1901; said fund to be designated as the "State Highway Maintenance Fund."

Section 4.—On or about September 1st, 1900, and biennially thereafter, the Department of Highways must certify to the State Controller the amount necessary to maintain said highways of the first class for the following two fiscal years. The Controller shall include this amount in his estimate of expenditures, and which, when paid into the State Treasury, must be credited to said fund.

Section 5.—The Department of Highways is hereby authorized to advertise for bids in two newspapers in the county in which the road is situated, for contracts to sprinkle, roll and maintain such State Highways as may be accepted under the provisions of this Act, and for the necessary appliances and machinery for said work. Said Department shall have the power to reject any and all bids, and order the work done by day's labor for an amount less than the lowest responsible bidder, and the Commissioner is responsible on his bond that the work shall be done according to the plans and specifications. Said bids to be filed with the County Clerk of the county in which said highway is situated, and to be opened by the Commissioner of the Department of Highways at the office of said clerk on a day specified in said advertisement for bids.

Section 6.—The money paid into the State Highway Maintenance Fund is hereby appropriated, without reference to fiscal years, for the exclusive purpose of maintaining State Highways. All claims against the State Highway Maintenance Fund must be made by warrants drawn against said fund by the State Controller, in the name of the person or persons rendering the services or furnishing material provided for by this Act, and must be audited and approved by the Commissioner of the Department of Highways and by the State Board of Examiners. The State Controller is hereby directed and authorized to draw said warrants, when so audited and approved, and the State Treasurer is authorized to pay said warrants, to the extent of moneys available therefor.

Section 7.—This Act shall take effect upon and after its passage.

An Act to Provide for the Location, Construction, and Maintenance of Highways, Owned or to be Acquired by the State of California, by the Levy of a Tax, and the Creation of a Fund Therefor.

The People of the State of California, Represented in Senate and Assembly, do enact as follows:

Section 1.—There is hereby levied annually, for each fiscal year, an *ad valorem* tax of 2¼ cents upon each $100 of value of the taxable property of the State, which tax should be collected by the several officers charged with the collection of State Taxes, in the same manner and at the same time as other State taxes are collected, upon all classes or any class of property, which tax is for the location, construction, and maintenance of highways owned or to be acquired by the State of California.

Section 2.—The State Board of Equalization, at the time when it annually determines the rate of State taxes to be collected, must, at the same time, declare the levy of said rate of 2¼ cents upon each $100 of value of taxable property, and notify the Auditor and Board of Supervisors of each county thereof.

Section 3.—The moneys collected from said rate, after deducting the proportionate share of expense of collecting from the same, to which other State taxes are subject, must be paid into the State Treasury, and be by the Treasurer converted into a separate fund, hereby created, to be called "The State Highway Fund."

Section 4.—The money paid into said "State Highway Fund" is hereby appropriated, without reference to fiscal years, for the exclusive purposes of locating, constructing, and maintaining the State Highways, and in no case shall any portion thereof be used for the acquisition of title to or rights of way over land or lands through or

upon which said State Highways may be located. All claims against said "State Highway Fund" must be audited by the Department of Highways, and approved by the State Board of Examiners, and payments shall be made out of said fund only upon warrants drawn against the said "State Highway Fund" by the State Controller, in the name of the person or persons rendering the services or furnishing material provided for in this Act; and the State Treasurer is hereby directed and authorized to pay said warrants.

Section 5.—No more than 8% of the money derived from said "State Highway Fund" shall be expended in any one county of the State in any one fiscal year.

Section 6.—All Acts or parts of Acts in conflict with the provisions of this Act are hereby repealed.

Section 7.—This Act shall take effect and be in force from and after its passage.

CHAPTER CXVII, STATUTES AND AMENDMENTS, 1897, TO BE AMENDED AS FOLLOWS:

Section 1.—The width of tires for wheels upon wagons or other vehicles to be used upon highways in the State of California shall be, for the following styles of wagons, as follows:

$1\frac{1}{2}$ and $\frac{5}{8}$-in. steel or iron axle; $2\frac{3}{4}$ and 3-in. steel or iron thimble skein axle; $2\frac{1}{8}$ and $2\frac{3}{4}$-in. tubular axle.	Not less than $2\frac{1}{2}$-in. tires.
$1\frac{3}{4}$ and $1\frac{7}{8}$-in. steel and iron axle; $3\frac{1}{4}$-in. steel or iron thimble skein axle; $2\frac{5}{8}$-in. tubular axle.	Not less than 3-in. tires.

All other vehicles with an axle greater in size or capacity than those above enumerated shall have tires of not less than 4 ins. in width.

Section 3 to be repealed.

Section 4 to be numbered 3.

Section 5 to be numbered 4.

SECTIONS 8 AND 9 OF CHAPTER CCLXXII TO BE AMENDED TO READ AS FOLLOWS:

Section 8.—The Department of Highways shall take possession, in the name of the State, and as rapidly as the funds provided therefor will permit, of all roads which have been or may be declared State Highways, and, in cases where the Legislature may define the general direction and route of a State Highway, the Department shall definitely locate the same upon the best grades and alignments, and as closely following the general lines defined by the Legislature as the topography of the country will permit, and in consonance with the

best interests of the State; and whenever the location of an existing county road, or any portion thereof, is such that it may be properly defined as a State Highway, or a portion thereof, then the location of such county road shall be utilized for said State Highway; *provided*, that all highways included within the boundaries of the lands of the State institutions, parks or reservations, now governed by bodies specified by law, are hereby expressly excepted from the jurisdiction of said Department.

Section 9.—The Department of Highways shall have power to locate, construct, and maintain State Highways to the extent of the funds available: and to this end advertise for and let all contracts; purchase, equip, and operate the necessary quarries; and acquire such other property necessary for the construction and maintenance of the roads provided for. Whenever it shall become necessary to construct any part of the System of State Highways, as herein provided for, the cost of which exceeds $500, the Department of Highways must have plans, specifications, and estimates therefor in triplicate, and must advertise for bids for a period of two weeks, in two papers of general circulation, and which shall give the lowest rate for publication, published, one at the point nearest to where the work is to be performed, and one at the State Capitol. Said advertisement shall be in the following form:

Department of Highways, Sacramento, Cal., ..., 18...

Sealed bids will be received by the Department of Highways of the State of California, at its office in the State Capitol, Sacramento, until...... o'clock,......M., 18.., for....in......county, California.

Plans and specifications for said work are on file in the office of said Department and in the office of the County Clerk of......County, at ......, Cal., to which bidders are hereby referred.

[SEAL.]

....

Highway Commissioner.

These recommendations were not fully considered by the Legislature of 1899. This was a year in which a senator was to be elected, which duty so engrossed the time of the Legislature that but little else was thought of.

Time was found, however, to re-enact the law providing for the construction of an important link of road between the easterly end of the roads leading easterly from the Yosemite Valley and those of Mono County on the other side of the Sierra Nevada.

The influence of so-called political considerations gave an instructive instance in the drafting of this Act. The roads to be connected are the Tioga Road and those of Mono County, in the basin of Lake Mono. The Tioga Road has been constructed across the Sierras at an elevation of about 9 500 ft., and into the basin of Mono Lake, at the Tioga Mine. From thence three possible routes exist:

First.—Down the cañon of Leevining Creek;

Second.—Northeasterly again over the crest of the Sierras at an elevation of over 10 200 ft., and down the cañon of Mill Creek past a mining settlement at which there are at present concentrated some forty votes;

Third.—To the southeasterly, also over the crest of the Sierras, through Mono Pass, at an elevation of over 10 200 ft., and down Bloody Cañon.

All considerations, economy, shortness of route, lighter grades, freedom from snow, stability of roadbed, suitability of materials, and the best interests of the state, are in favor of the first—the Leevining Creek route.

These facts were fully brought out; yet the legislator who drafted and introduced the bill could not be induced to draw it so as to apply to the best route, but yielded to the importunities of the voters on the Mill Creek route, and drew the bill so that the diversion of the fund to that route could be possible. At this date, it is yet possible that the best of the routes may, through these influences, be abandoned for the worst.*

The attempt to introduce method in road building, however, has not been without result; a much better understanding is had throughout the state, and many practices have been corrected. It must be admitted, however, that political road building so far has had the best of the struggle.

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* Since the above was written, the U. S. Commission on Roads in the Yosemite National Park has confirmed the selection of the Leevining Creek route. Pp. 11-14 of Report.

Vol. XXVIII. FEBRUARY, 1902. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS,
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

LINE AND SURFACE FOR RAILWAY CURVES.

By Charles C. Wentworth, M. Am. Soc. C. E.

To be Presented April 2d, 1902.

It is safe to say that there are in existence thousands of miles of railway track the original center line of which may be described, for the purposes of this paper, as a series of tangents connected by circular curves. Right of way was secured and the earthwork completed, using this center line as the base of measurement; and, finally, track was laid to the same center line and the whole turned over to the operating department.

A subsequent retracing of the original center line would show that it had been found necessary, or at least advisable, to deviate from it materially in order to secure the smooth riding of trains. Short tangents, connecting curves turning in opposite directions, have been shifted at each end, away from the centers of these curves, thus increasing the total amount of curvature; or the points of curve and tangent have been moved closer together, thus decreasing the length of the straight track between them. In the latter case it is not unusual that the original curve has been materially sharpened at the end of the flat curve introduced; and cases have been observed in which

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers with discussion in full will be published in *Transactions*.

[illegible] was deflected at a point a short distance from the original [illegible] to secure a lighter approach to the original curve.

[illegible] is an attempt to indicate what was wrong with the [illegible] line, and to propose simpler means for correcting the [illegible] than those now in use.

The conditions to be met are:

First.—The method must be of the simplest kind that will be theoretically exact, and, as a consequence, practically so. If the most [illegible] calculator had to perform in the field, and with half-frozen fingers, the operations called for by some methods he would appreciate the importance of this first condition.

Second.—The position of the original tangents must not be altered. It is impracticable to shift long tangents, and the shifting of short tangents involves such a change in the angles of intersection that the problem becomes indeterminate.

Third.—The length of the center line must not be altered by the revision. Grades, distances and right-of-way matters require this. A multiplicity of long and short stations is apt to be a never-ending source of future uncertainty.

Fourth.—The resulting center line, and the changes in the elevation of the outer rail involved by the revision, must be such as can be followed exactly in practice, without such practical alterations as are sometimes found necessary for successful operation.

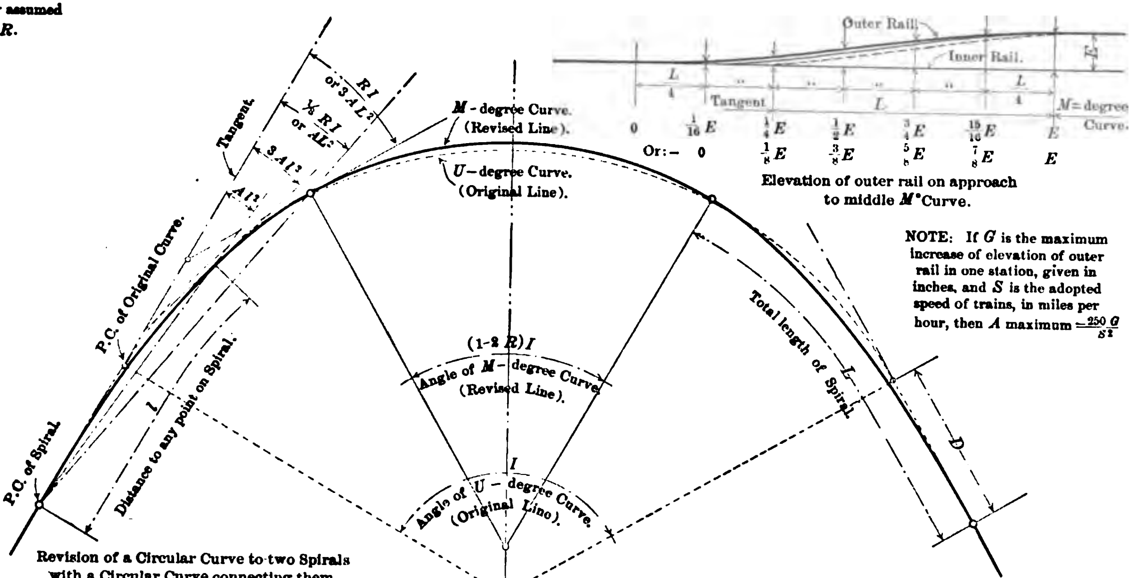
The principles involved may be stated as follows: In order to impart a given rate of motion to a heavy body, a force must be used. The smaller the force, the less will be the jar caused by it while acting. The smallest force that will impart the given motion is the one that acts uniformly during the entire given time. The total amount of motion imparted by such a uniform force is proportional to the square of the time, and the rate of motion is proportional to the time.

The motions imparted to a car leaving a tangent and entering a curve are two in a horizontal and one in a vertical plane. To these motions the principles given hereinbefore are to be applied. Each motion being taken care of separately, the result will be the best that can be gotten out of the situation.

The first motion in a horizontal plane is one about the center of the curve. Inasmuch as on a circular curve the departure from a tangent

Values of B for assumed values of R.

R	B
$\frac{1}{12}$	1.0128
$\frac{1}{10}$	1.0188
$\frac{1}{9}$	1.0235
$\frac{1}{8}$	1.0283
$\frac{1}{6}$	1.0496
$\frac{2}{10}$	1.0705
$\frac{1}{4}$	1.1080
$\frac{3}{10}$	1.1594
$\frac{1}{3}$	1.1858
$\frac{4}{10}$	1.2603
$\frac{1}{2}$	1.3900



NOTE: If G is the maximum increase of elevation of outer rail in one station, given in inches, and S is the adopted speed of trains, in miles per hour, then A maximum $=\frac{250\,G}{S^2}$

Revision of a Circular Curve to two Spirals with a Circular Curve connecting them.

Position of tangents and length of center line unchanged.

Given:– U and I

Assumed:– $\frac{\text{Tangential angle of each spiral.}}{I} = R$

then $\left\{ \begin{array}{l} M = BU \\ D = (R + \frac{1}{6})\frac{L}{M} - \frac{I}{2U} \\ A = \frac{M^2}{12\,RI} \\ L = \frac{2\,RI}{M} \end{array} \right\}$ in which $\left\{ \begin{array}{l} A = \text{deflection for the first 100 ft. on spiral.} \\ B = 1 + 1.896\,R^2 - 0.672\,R^3 \end{array} \right.$

All distances in 100-ft. stations, and all angles in degrees.

Properties of Spiral:

Distance along spiral	1.00	2.00	3.00 etc.	l	L
Deflection from tangent	A	$4A$	$9A$	Al^2	$\frac{1}{3}RI$
Tangential angle	$3A$	$12A$	$27A$	$3Al^2$	RI
Degree of curvature	$6A$	$12A$	$18A$	$6Al$	M

FIG. 1.

at a given point is initially proportional to the square of the distance run, this motion requires no treatment, except that, in order to make the deviating force as small as possible, the amount of deviation should also be as small as possible, or the radius of curvature as great as possible, a fact which is well recognized.

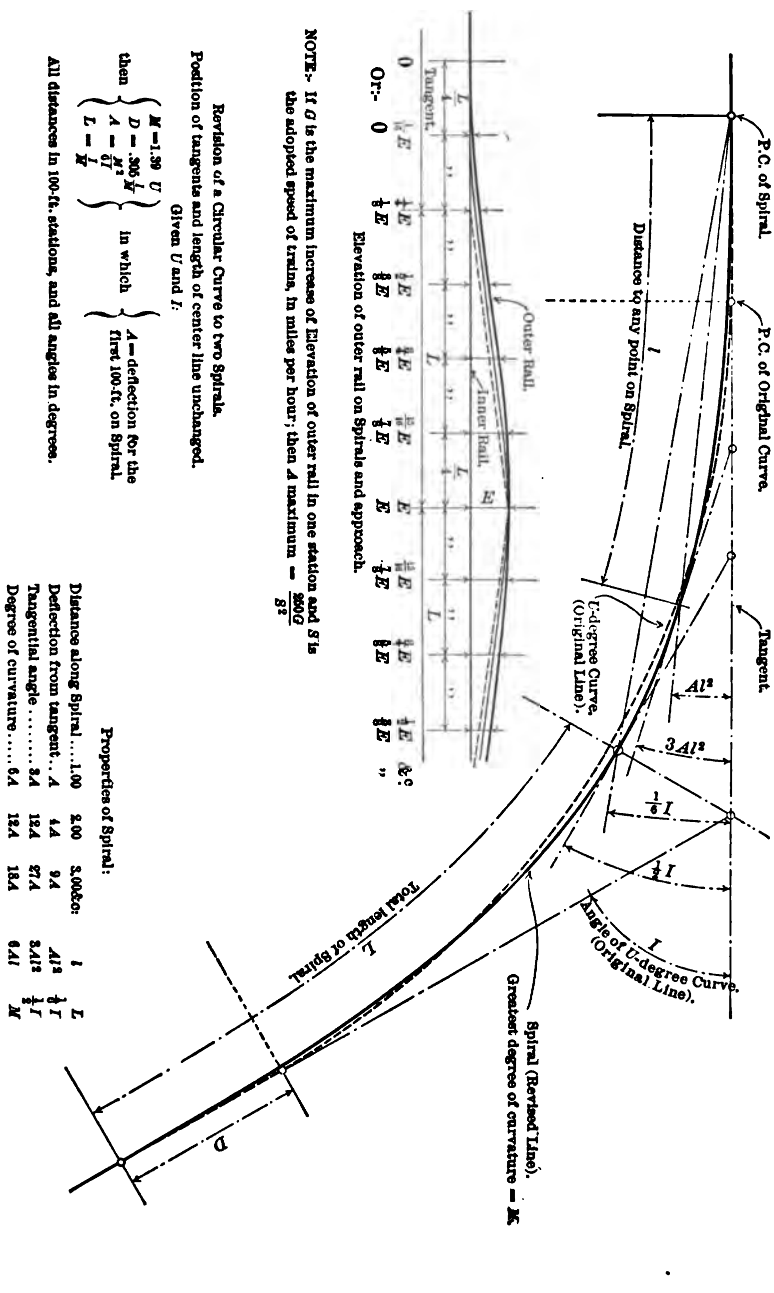
The second motion in a horizontal plane is one of each car about its own center, as if it were mounted on a turn-table. In order that the force producing this motion be as small as possible, as stated hereinbefore, the amount of angular deviation must be proportional to the square of the distance run; the speed along the track being uniform. This may be accomplished by using such an approach curve that its tangential angle at any point is proportional to the square of the distance of such point from the P. C., measured on the arc.

The motion in a vertical plane is that caused by the deviation of the car from the vertical, due to the elevation of the outer rail. If it be assumed that the angular departure from the vertical is proportional to this elevation, then this elevation must vary as the square of the distance run until a certain rate of motion is attained. The line of increase in elevation may then become straight, continuing so until it is necessary to stop the motion, when the motion is to be eased off in the same manner that it was created.

Revisions of a center line, as herein indicated, can be made much more advantageously prior to the construction of a railway than subsequently, as then they can be made on a scale commensurate with the dignity of the undertaking. There is no better way to project locations of railway, in a difficult country, than with circular curves on contour maps. In revising the center line of existing track, circular curves are the subjects of revision. A circular curve has then been made the basis of revision on the lines suggested, and the results obtained, all of which are in strict accordance with the conditions and principles before mentioned, are shown in Figs. 1 and 2.

These figures are intended to be clear as to their presentation of the subject, though necessarily any new method requires some additional explanation. The following examples will make the matter quite clear:

Fig. 1 treats of such revisions of a circular curve as require a middle circular curve to connect the spirals.



P.C. of Spiral.
P.C. of Original Curve.
Tangent.
Distance to any point on Spiral.
l
U-degree Curve. (Original Line).
Al^2
$3Al^2$
$\frac{1}{6}I$
$\frac{1}{2}I$
I
Angle of U-degree Curve. (Original Line).
Spiral (Revised Line).
Greatest degree of curvature = M.
Total length of Spiral.
L
D
Properties of Spiral:
Distance along Spiral.....1.00 2.00 3.00 &c: l L
Deflection from tangent..A $4A$ $9A$ Al^2 $\frac{1}{3}I$
Tangential angle.........$3A$ $12A$ $27A$ $3Al^2$ I
Degree of curvature.....$6A$ $12A$ $18A$ $6Al$ M
Outer Rail.
Inner Rail.
Tangent.
L
E
0 $\frac{1}{8}E$ $\frac{1}{2}E$ $\frac{9}{8}E$ $\frac{15}{8}E$ $\frac{31}{16}E$ E $\frac{15}{16}E$ $\frac{7}{8}E$ $\frac{1}{8}E$ &c
Or:- 0 $\frac{1}{8}E$ $\frac{1}{4}E$ $\frac{3}{8}E$ $\frac{5}{8}E$ $\frac{7}{8}E$ E $\frac{7}{8}E$ $\frac{5}{8}E$ $\frac{3}{8}E$ "
Elevation of outer rail on Spirals and approach.
NOTE- If G is the maximum increase of Elevation of outer rail in one station and S is the adopted speed of trains, in miles per hour; then A maximum $= \frac{380G}{S^2}$
Revision of a Circular Curve to two Spirals.
Position of tangents and length of center line unchanged.
Given U and I:
then $M = 1.39\ U$, $D = .306\ \frac{I}{M}$, $A = \frac{M^2}{6I}$, $L = \frac{I}{M}$ in which A = deflection for the first 100-ft. on Spiral.
All distances in 100-ft. stations, and all angles in degrees.

FIG. 2.

Fig. 2 considers curves made up of spirals only, as would be the case in short curves generally, or in comparatively long curves when liberally treated, and when the increase of curvature (39%) does not prohibit.

There may be, for instance, a 6° curve for twenty stations, the total angle of intersection being 120 degrees. If the tangential angle of each spiral be assumed as being 30°, then $R = \frac{1}{4}$, and $B = 1.108$; so that, for the degree of curvature for the middle curve, $M = 6.648°$, or 6° 39′.

For the distance from the P. C. of the original curve to the P. C. of the spiral, measured on the tangent, $D = 3.538$, or 353.8 ft.

For the angle of deflection from the original tangent, to be used to set a stake 100 ft. from the P. C. of the spiral, $A = 0.1228$, or 0° 7.37′

For the length of the spiral $L = 9.025$, or 902.5 ft., all being figured from the formulas given in Fig. 1.

As this spiral extends through nine stations, the deflections, for each station, successively, are 0° 7′, 0° 29′, 1° 6′, 1° 58′, 3° 4′, 4° 25′, 6° 1′, 7° 52′ and 9° 55′. Then the deflection for 902.5 ft., or the total length of the spiral, is one-third of the assumed tangential angle, or 10°, and the tangential angle 30°, as assumed. Spirals can be run in thus from both tangents, and then connected by a 6° 39′ curve between them for the remaining 60° of total angle.

It may be noted that the length of the revised line is 2707.5 ft., as compared with 2707.6 ft. by the original line, measured in both cases between the P. C. and P. T. of spirals. Also, that both lines, as projected on the long chord connecting the P. C. and P. T. of spirals, agree as to length, 2008.6 ft. The second and third conditions, therefore, are complied with.

If the spirals in this case be thought unnecessarily long, the tangential angle of each spiral could be assumed as being, say, 15°, in which case $R = \frac{1}{8}$. Then, from Fig. 1,

$$M = 6.170°, \text{ or } 6° \ 10';$$
$$D = 2.156, \text{ or } 215.6 \text{ ft.};$$
$$A = 0.2115, \text{ or } 0° \ 12.7';$$
$$L = 4.862, \text{ or } 486.2 \text{ ft.}$$

It may be desired to revise a circular curve in such manner that the revised line will be all spiral, as shown in Fig. 2. In a 10° curve for 600 ft., or 60°, we have, by substitution.

$M = 13.9°$, or $13° \ 54'$;
$D = 1.316$, or 131.6 ft ;
$A = 0.5367$, or $0° \ 32.2'$;
$L = 4.316$, or 413.6 ft.

The theoretical elevation, in inches, E, for a given degree of curvature, D, and speed, in miles per hour, S, may be found by the formula, $E = \frac{S^2 \, D}{1500}$. It is not the province of this paper to attempt to prescribe a certain elevation for a given degree of curvature and speed, because there is room for a considerable difference of opinion on this subject.

This is due to the fact that it is the manner of attaining an assumed elevation, and the uniformity with which it is maintained when reached, that is of prime importance, rather than the absolute elevation itself. This will be evident from the consideration of a piece of straight track, perfect in all respects except that one rail is 1 in. lower than the other for a space of, say, a mile. This will be the best riding piece of track on its division—better perhaps than if the rails were on the same level—because the wheel flanges will run close to the low rail rather than deviate from rail to rail, while the difference of elevation will be almost, if not quite, imperceptible to anyone in an ordinary car. If this be granted, and it will be found correct, 1 in. more or less than the theoretical elevation cuts no figure, as far as smooth riding is concerned, after proper approach curves have been provided.

It will be seen from Figs. 1 and 2 that elevation is given the outer rail at the P. C. of the spiral, notwithstanding the fact that the radius of curvature there is infinite. This is done because a car is not a rigid body with respect to its trucks, and, in order to impart a given motion to the body of the car, such motion must be imparted to the trucks in advance of the time when it will be required by the car itself. Further, it will be seen that it is impossible to provide proper vertical curves at the ends of the grade of elevation unless either an elevation of the outer rail be given at the P. C., or the rate of grade increased. The vertical curves used in the easements to the elevation grades in the illustrations are common parabolas.

If a point be taken on a given tangent, and a polygonal segment, with 100-ft. sides, be staked out therefrom, such that the angle between the first side and the tangent is A degrees, the angle between the tan-

gent and the end of the second side is 4 A degrees, or, to the end of n sides, $n^2 A$ degrees, and pass a curve through the apices of this polygon, the result will be the spiral of this paper. This curve is not a cubic parabola, but departs from its tangent at a more rapid rate. Consequently, the properties ascribed to it in Figs. 1 and 2 can be so ascribed with much more accuracy than would be the case with the cubic parabola. It fulfills accurately the assumed conditions, and is capable of being harnessed in such way that the resulting formulas are much simpler, being free from even the ordinary trigonometrical functions, as may be seen from the illustrations.

The writer will not herein go over the reductions necessary for the production of the given formulas, but will leave them, in the hope that they may be found useful in a field where little has been done, though much is desired.

Vol. XXVIII. FEBRUARY, 1902. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

IS IT UNPROFESSIONAL FOR AN ENGINEER TO BE A PATENTEE?

By A. R. Eldridge, M. Am. Soc. C. E.

To be Presented April 16th, 1902.

It may be, that, when drilling for water, oil is struck instead. Thus it was when the writer was reading the discussion on the paper* by Leonard Metcalf, Assoc. M. Am. Soc. C. E., he came upon Mr. James Owen's vehement denouncement of an engineer taking out a patent upon any meritorious product of his brain and energy, and, for the first time in his limited professional career, had "the law laid down" to him, that such was a gross violation of professional ethics. Thinking that others in the profession may be as benighted as he upon what might be, to some, a most momentous question, is his apology for inviting a discussion of this subject.

The writer would state, at the outset, that he has never applied for a patent upon any article whatsoever, not even for a washing machine or a car coupler, the two articles which keep the Patent Office working overtime; and will further state that he has no patent-

* "The Antecedents of the Septic Tank," *Transactions*, Am. Soc. C. E., Vol. xlvi, p. 456.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers with discussion in full will be published in *Transactions*.

able schemes in sight at the present writing. His presentation of the subject is, therefore, from an unbiased and unprejudiced point of view, and whatever opinions he may advance are entirely impersonal.

Someone once said, and most truly, too, that an engineer's capital consists of his brains. His brains make up his stock in trade; his brains, or rather their products, he sells. Others may sell the products of their mills and factories; the engineer sells the products of his trained intellect—no other goods has he to place upon the marts of trade. Wherefore should he then be debarred from selling those products to the best advantage to himself, provided always that they are sold "openly and above board" and not sneaked into a piece of work or a contract? By the latter terms the writer means that it would be manifestly wrong for an engineer in authority to specify absolutely the use of certain devices or articles of which he was patentee and owner. Let his employer do that, if the articles or devices in question are so meritorious that they deserve exclusive recognition. It might also be questionable for an engineer to patent a device worked out while in the employ of a client; for it may be, as Mr. Owen says, that in that case, the invention would belong to the client and not to the engineer. That, however, seems to be more a point of law than of ethics, and is not germane to the present discussion.

The point at issue, then, simmers down to the question: Can an engineer, working on his own lines, patent any device, which he may discover or invent, without a violation of the ethics of the engineering profession?

Common sense answers "Yes," unreservedly, but Ethics may answer, just as emphatically, "No."

Let it be supposed, and the supposition is within the bounds of both possibility and probability, that an eminent engineer, one of the leading lights of the profession, should, by chance, stumble upon a decided improvement in egg-beaters. Would he debase the ethics of his profession by taking out a patent on his discovery or invention? The writer hardly thinks that the engineering world would decry such an action; wh— hen, should it object to his taking out a patent on a new and improved method of rolling steel rails, on an improvement in the valve gear of an engine, or on the construction of a freight car. There seems to be no reason, except intangible "Ethics," and

ethics, like charity, may be stretched indefinitely to cover a multitude of things, even so far as to become a veritable bogie man and a hamper to the "younger" members of the profession; and, in passing, it may, perhaps, be worth while to note that to some of the "younger members" may be given the credit for some of the most valuable discoveries of the engineering world. For example, W. J. M. Rankine is considered, the writer believes, quite an authority on more than one engineering subject, yet even at the time of his death he was little more than a "young" member of the profession.

To look at the matter in another light: Perhaps for an engineer to patent an invention shows a spirit too "money-grasping," instead of working for the good of mankind. That is a pretty theory, but it will hardly hold water when put alongside of the bills rendered for expert engineering opinion and advice. Do not think from this that the writer is an advocate of "cheap" work. Like the rest of his professional brothers, he is not working for his health, and he believes that an engineer should receive full compensation for any knowledge that he may have to sell. Whether the engineer can pass an opinion at a moment's notice, or whether it will take a month of patient research to reach the same conclusion, makes no difference to the client. The opinion is what he wants; and if his engineer is so well posted that he can give it at once, it is simply so much the better for the engineer. He has the goods, he can deliver them promptly, and should be paid accordingly.

The writer hardly thinks it will be contended that an engineer is not in business for all the money he can make in an honorable and legitimate manner. Such a contention would be foolish in the extreme, with a few very rare exceptions; and he also feels assured that every engineer has a contempt for the quacks and "cut-throats" who are in this, as in every other profession; and further, that all engineers are willing and anxious to see their brethren get just and full recompense for their services, so that, in spite of all that may be said to the contrary, engineers are simply business men, and, as such, are entitled to full compensation for their wares, the products of their brains.

Again, the writer does not see or hear of any objection being raised when an engineer copyrights a book which he writes or even compiles, yet, wherein, pray, is to be drawn the fine distinction be-

tween a patent and a copyright? An article, a device, a method of manufacture may be "patented," whereas a book may be "copyrighted." In either case others than the owners of the patent or copyright are restrained from using the article or the contents of the book without compensation, in one form or another, being paid to the holder of the patent or the copyright. Patent! Copyright! One all wrong; one all right! Rather a case of Tweedledum and Tweedledee, isn't it?

The writer would not have to go very far to find one, or more, engineers, leading ones in the profession, too, who are directly interested in patented articles, and they are not "younger members" of the profession, either. Furthermore, the writer does not believe that they have in the least violated the ethics of the profession of which they are to-day ornaments.

It is virtually impossible to name a book or treatise, written by an engineer, which is not protected by copyright.

In conclusion, it may be stated that the very words condemning the taking out of patents by engineers, the very sentences which caused the writing of this article, are, themselves, "patented," and to reproduce them the publisher of the reproduction must pay, not in money it is true, but by printing also the full title of the paper from which they are taken, the name of the author, etc., according to the following, which is found on the title page of the "*Proceedings* of the American Society of Civil Engineers," to wit:

"Reprints from this publication, which is copyrighted, may be made on condition that the full title of Paper, name of Author, page reference, and date of presentation to the Society, are given."

Vol. XXVIII. FEBRUARY, 1902. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE STIFFENING SYSTEM OF LONG-SPAN SUSPENSION BRIDGES FOR RAILWAY TRAINS.

By JOSEPH MAYER, M. Am. Soc. C. E.

TO BE PRESENTED APRIL 16TH, 1902.

The improvements in the quality of the materials used for the construction of bridges have gradually increased the largest practicable distance between the piers, or the length of span. This is from 200 to 300 ft. for stone, concrete and timber bridges, and a maximum of 2 000 ft. for bridges of the best structural steel now obtainable.

The progress in the manufacture of steel wire has made it practicable to construct bridges of a span of over 3 000 ft. Long-span bridges generally cross navigable waters, where the difficulty of erection limits the choice to cantilever or suspension bridges. Different locations offer unequal advantages for the two types. In some locations natural rock can be used for the anchorages of a suspension bridge; in others, these anchorages have to be built of concrete or masonry on deep and expensive foundations. It is, therefore, impossible to fix accurately the limits of span for the economical use of the two types without investigating the proposed site.

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Another factor of prime importance, extending or limiting the field for the economical use of suspension bridges, is the nature of the moving load and the permissible maximum grade on the structure. If the moving load consists of street cars, wagons, carriages and people on roadways and sidewalks, the bridge will generally be nearly uniformly loaded over its whole length, and a grade of 3% is unobjectionable. If the bridge is for railroad trains the moving load will often cover only a part of its length, the other part being entirely unloaded, and a grade of more than 1% may be very objectionable.

The unequal loading of different spans, or of different parts of the same span, of a suspension bridge, is the most important cause of its deformation. The permissible maximum grade is the main factor that fixes the allowable deformation.

To diminish the deformation of a suspension bridge under unequal loading, a stiffening system is required. This will be heavy when there is very unequal loading over the length of the bridge and when the permissible deformation is small. It will be light when the load is nearly uniform over the length of the bridge and when the permissible deformation is great. The former is the case for railroad bridges; the latter, for highway bridges. This is the main reason why highway suspension bridges are economical for nearly all spans when the site is favorable for the anchorages, while railway suspension bridges are economical only for very long spans.

When the span exceeds 800 ft. the conditions must be extremely unfavorable for the anchorages to make a highway suspension bridge uneconomical. When the span exceeds 1 500 ft. a railway suspension bridge becomes economical with natural rock anchorages. When the span exceeds 2 000 ft. the suspension bridge is the only practicable type.

The essential feature characterizing and distinguishing a long-span suspension bridge consists in one or more carrying cables, of steel wires or wire ropes, attached to anchorages at the ends and passing over supporting towers. These cables take the place of the tension chords of a truss bridge, while the compression chords are replaced by the anchorages. The web system of a truss bridge is replaced, either by suspended stiffening trusses, or by bracing between cables placed above each other in vertical or nearly vertical planes. The cables in the latter case are the chords of the stiffening trusses.

The cables between the towers and the anchorages may be used to support the shore spans, as in the existing New York and Brooklyn Bridge, or the shore spans may be either partly or wholly supported by piers. The cables, in the last case, pass in nearly straight lines from the towers to the anchorages. There may be moving or fixed saddles on the top of the towers to receive the cables. In the latter case the towers oscillate with their expansion and contraction. The cables may be in vertical planes or in slightly inclined planes; in the latter case they are said to be cradled.

The stiffening trusses may be continuous at the towers and in the center of the main span, or they may have two or three hinges; they may have a depth equal to one-twentieth of the length of the main span, or their depth may be only one-one hundredth, or less, of this length. There may be two or more stiffening trusses.

Other methods of stiffening long-span suspension bridges are possible, but will not be considered, as their inferiority is now generally conceded.

Suspension bridges for railways differ from those for highways by the greater amount of the forces tending to produce deformation, and by the smaller deformation that is permissible. Their stiffening system, therefore, is of much more importance than that of highway suspension bridges. It is, at the same time, the feature about which there is the greatest difference of opinion among engineers, showing itself in fundamental differences in the designs proposed. The writer, therefore, has selected the stiffening system for discussion. Only two types of stiffening systems will here be considered: Suspended stiffening trusses, and braced cables. For both of them the questions arise: Whether to use hinges or not; and the proper depth between the chords of the stiffening trusses.

Suspension bridges, especially those with braced cables, have many features in common with arches. In both suspension bridges and arches the end reactions have a horizontal component; in truss bridges, they are vertical. While suspension bridges tend to pull their anchorages toward each other, arches tend to push their abutments apart. The calculations of the stresses of arches and of the main span of suspension bridges with braced cables are nearly alike. Inferences, therefore, have been drawn from the general dimensions of arches that have proved satisfactory to the best general dimensions of suspension bridges.

Two very important differences between long-span suspension bridges and arches, however, have a direct bearing on the determination of the best general dimensions of the former. The ends of the main span of a suspension bridge are supported on high towers and connected with the anchorages in their rear by elastic cables. These ends, therefore, are far from fixed in position. The ends of arches are practically fixed. The cables of long-span suspension bridges, corresponding to the chords of a steel-arch bridge, are made of wire having an elastic strength three to four times as large as that of the structural steel of the chords of the arch. The permissible unit stresses in the cables and the consequent deformations, therefore, are very much larger than the unit stresses in the chords of an arch bridge and its deformations.

These two differences between arch and suspension bridges, both having the effect of largely increasing the deformations of a suspension in comparison with that of an arch bridge of similar general dimensions, are evidently important in determining those general dimensions which will keep the deformations within given narrow limits. No reliable inferences, therefore, can be drawn from the proper general dimensions of arches to those of suspension bridges.

The deformations of ordinary truss and cantilever bridges, produced by loads and changes of temperature, are of little importance in determining the general dimensions; they become important in arches with less than three hinges, and they are the governing factor in suspension bridges.

The advantages of the various types and general dimensions of suspension bridges can only be shown on concrete examples. There exist no suspension bridges of the kind here considered. A great amount of thought, however, has been expended to develop a satisfactory design for a suspension bridge for railroad trains across the Hudson River, in New York City.

These designs furnish the concrete material on which the arguments for the various types can be tested. Such a bridge should enable the long-distance passenger trains of the railroads having terminals across the Hudson to come to a central station in the hotel and residence district of New York City. It should enable the New York Rapid Transit trains and the surface cars to proceed to the suburbs in New Jersey so as to give direct communication, without change, between

all parts of New York City and the New Jersey suburbs. It might also be used to some extent by freight trains, especially if a proper freight approach can be secured in New York City. It is evident that many tracks will be required to perform this service.

There will be needed: Two tracks for freight trains, if freight business is contemplated; six tracks for accommodating the suburban traffic, mostly with lower New York (this traffic would use the elevated and underground roads); two tracks for surface cars connecting the near regions east and west of the bridge; two tracks for long-distance passenger trains going to a central station.

The bridge, therefore, should have ten passenger tracks, and perhaps two freight tracks.

For the purpose of comparing the merits of various types for a bridge across the Hudson, the writer, therefore, will use a bridge having twelve tracks, of which two are for freight trains, two for long-distance passenger trains, six for trains of the elevated and underground roads of New York City and two for surface cars.

Such a bridge has sufficient capacity for the business it can secure in the near future. The distant future may bring other competing bridges or tunnels, therefore it need not be considered.

The moving load would consist of two freight trains, each 1 000 ft. long and weighing 3 000 lbs. per linear foot; two long-distance passenger trains, each 1 000 ft. long and weighing 1 500 lbs. per linear foot; six Rapid Transit electric trains, each 500 ft. long and weighing 1 200 lbs. per linear foot.

The surface cars, on the two tracks provided for them, should run at a speed of at least 15 miles per hour. They would, therefore, be twice as far apart as on the street approach; a distance of 100 ft. from center to center of cars would be closer than practicable. This distance, with cars weighing 40 000 lbs., gives a load of 400 lbs. per linear foot of track.

For the calculation of the cables, anchorages and the towers above the floor level this load is equivalent to 8 421 lbs. per linear foot of bridge, covering the whole length of the main span. The writer, therefore, will assume a moving load of 8 500 lbs. per linear foot of bridge for these calculations.

For the calculation of the stiffening trusses, the loads on the surface-car tracks may be neglected, as they are nearly uniformly dis-

tributed over the length of the bridge. The stresses produced by the trains 1 000 ft. long and those produced by the trains 500 ft. long would have to be separately calculated and then added, if the exact stresses corresponding to these loads are wanted. No equivalent load of one length will give the same stresses in every member of the stiffening trusses as the two loads of different lengths.

For the purpose of comparing the total weights of different designs, an equivalent load, giving the same average stresses and total weights as the two loads of different lengths, may be found.

In a span of 2 800 ft., from center to center of end hinges, a train 500 ft. long will give, on an average, stresses about 64% as large as those produced by a train 1 009 ft. long of the same weight per linear foot. The equivalent load of 1 000 ft. length for the calculation of the stiffening trusses, therefore, is 13 600 lbs. per linear foot of bridge. This load cannot be used for finding the correct stresses in the different truss members, but only for finding the total weights of the trusses.

For a bridge of 2 800 ft. span between the end-hinges of the stiffening trusses the total dead load of the main span, inclusive of the cables and suspenders, and 500 lbs. per linear foot of bridge for pipes, etc., is 28 000 lbs. per linear foot. This is the result of an exact estimate based on an actual design with deep three-hinged stiffening trusses.

With these data it is now possible to determine the deformations of the bridge caused by the moving loads and changes of temperature, and to estimate the importance of the deformations in selecting the design.

The bridge here considered has a span of 2 850 ft. from center to center of towers. We will first consider a design with deep, three-hinged stiffening trusses, and with the shore spans supported on piers.

The rear cables are 1 395 and 1 851 ft. long. The dip of the cables of the main span is one-eighth of the span from center to center of the towers. The ends of the cables are 500 ft. lower than their highest points at the towers. The drop of the cables at the center of the main span, due to a rise of temperature of 120°, is 7.4 ft. If it be assumed that wire having an elastic limit of 170 000 lbs., and an ultimate strength of at least 200 000 lbs. per square inch, is used in the cables; and if

the cables are properly designed, so that the bending stresses in them are small and well known, a unit stress, for dead and live load, of 70 000 lbs. per square inch may be taken. The unit stress from live load alone will then be $\frac{8\ 500}{36\ 500} \times 70\ 000 = 16\ 300$ lbs. per square inch. The rear spans of the cables are 1 740 and 1 260 ft. long. The weight of the rear cables is 6 400 lbs. per linear foot of bridge. From these data the drop of the cables at the center of the main span due to the moving load has been calculated. It is 6.4 ft. The total variation in the elevation of the cables at the center of the main span, therefore, is 13.8 ft.

If the tracks are level in the lowest position, the grade in the highest position of the main span will be practically uniform, and equal to 1%, rising from the towers to the center of the span. It is assumed that the stiffening trusses have three hinges. If they are 140 ft. deep in the center of the half spans and 60 ft. deep at the towers and the center of the span, then the upward bending of each half span for the highest position of the main span is only $\frac{3}{4}$ in. above the curve for the mean load and temperature. The stiffening trusses of each half span remain practically straight for uniform moving loads of any amount and for all temperatures.

If the stiffening trusses have only two end hinges and no center hinge, and if the tracks are level in the lowest position of the main span, then the whole span will deflect approximately in the arc of a circle. The grade at the towers will be 2% in the highest position of the main span, and will gradually decrease to nothing at the center of the main span. If the stiffening trusses were fixed at the towers and without a center hinge, the maximum grade would be 2%, but it would occur near the center of each half span.

Three-hinged, deep, stiffening trusses, therefore, have the advantage that the maximum grade is only one-half of that which occurs if there are fewer than three hinges.

The other principal factors influencing the maximum grade are the dip of the cables in the main span and the length of the back spans of the cables. The shorter the back spans of the cables and the larger their dip in the main span, within practical limits, the less is the maximum grade. The maximum grade can be reduced in all cases by building the tracks with a sag in their lowest position.

The use of three-hinged, deep, stiffening trusses for railroad suspension bridges, however, has other and more important advantages. They consist mainly in their greater economy, in smaller secondary stresses due to the deformation, and in closer agreement between the actual and calculated stresses. To prove this it is necessary to calculate the stresses due to the dead and moving loads, the changes of temperature, and the wind pressure in suspension bridges with stiffening trusses of three, two or no hinges.

Stresses Produced by the Change in Length of the Cables in Suspended Stiffening Trusses with Two End-Hinges.

This change in length of the cables and of their consequent elevation in the main span is due to changes of temperature and moving load. To calculate the stresses produced, the sections of the stiffening trusses should be known. It will be assumed that the stresses per square inch in the chords of the stiffening trusses, produced by their rise and fall with the cables, are uniform over the whole length of the trusses. This is more nearly true in properly designed stiffening trusses than the frequent assumption that the moments of inertia of the stiffening trusses are uniform over their whole length. The writer will neglect the influence of the deformation of the web members, which is small in the shallow trusses here considered. In this case the trusses will deflect in the arc of a circle. If δ is the rise of the cables at the center of the main span; if the stiffening trusses are assumed to be straight before the rise, they will, after the rise, be arcs of circles with a radius $= R$. If the span between the end hinges is l, then $R = \frac{l^2}{8\,\delta}$. If d is the depth of the stiffening trusses, and t is the stress per square inch in their chords produced by their bending, then $t = \frac{4\,\varepsilon\,\delta\,d}{l^2}$, where ε is the modulus of elasticity of the chords. This is, on account of splices and tie-plates, somewhat larger than that of steel, and may be taken at 30 000 000 lbs. per square inch of gross section. If special values for d, δ, and l are introduced into this formula, as follows: $d = 60$ ft.; $l = 2\,800$ ft., $\delta = 6.9$ ft.; then $t = \pm\, 6\,337$ lbs. If d is taken equal to 140 ft., then $t = \pm\, 14\,786$ lbs. The δ used above is one-half the total variation in the elevation of the cables at the center of the main span. If the suspenders are so adjusted that there are no stresses in the stiffening trusses at the mean

temperature and with one-half of the largest uniform moving load on the bridge, then the stresses produced by the variation in the elevation of the cables are the smallest possible. They are then of opposite sign and equal for the two extremes of temperature and moving load.

It is not so important, however, to find the largest amount of these stresses due to the variation in the elevation of the cables as to find those stresses which coincide with the largest stresses from the moving load. The variation in the moving load stress in the cables which occurs at the same time with maximum stresses in the stiffening trusses due to the moving load is about 61% of 6.4 ft. = 3.9 ft. The corresponding δ is $= \frac{1}{2}$ (7.4 + 3.9) = 5.65 ft.

The values of t for stiffening trusses 60 ft. and 140 ft. deep, which must be considered in obtaining the total maximum stresses in the stiffening trusses are, therefore, $t_{60} = \pm$ 5 190 lbs.; $t_{140} = \pm$ 12 110 lbs.

STRESSES PRODUCED BY THE CHANGE IN LENGTH OF THE CABLES IN SUSPENDED STIFFENING TRUSSES OF THREE HINGES.

The writer has published,* in *Engineering News*, methods for calculating these stresses, and will use the formulas given there: $T = \frac{\delta_1 (w + q) L^2}{h l^2}$; where T is the load per linear foot of bridge which will produce on a span, of the dimensions of the half span of the stiffening trusses, and freely supported at both ends, stresses equal to the stresses produced by the variation in the length of the cables occurring at the same time with the maximum moving-load stresses in the stiffening trusses. In three-hinged stiffening trusses those stresses which are due to the lengthening of the cables from moving load are of opposite sign to the maximum moving-load stresses occurring at the same time; their neglect is therefore on the safe side, giving maximum stresses considerably too large. The δ_1 in the above formula is therefore one-half the change in the elevation of the cables at the center of the main span due to changes of temperature only.

$\delta_1 = 3.7$ ft.; $w + q = 34\,000$; $L = 2\,850$; $l = 2\,800$; $h = \frac{L}{8}$.

$w + q$ is intentionally taken less than the maximum value, for the purpose of partly neutralizing the error arising from the neglect of the stretch of the cables by the moving load, which produces negative stresses.

* *Engineering News*, November 7th and December 12th, 1901.

If these values are introduced in the formula for T we obtain $T = 366$ lbs. The stiffening trusses are 140 ft. deep at the center of the half spans. We obtain, therefore, for the stress in each chord of the stiffening trusses at the center of the half span, $\pm$ 320 400 lbs. The formula used neglects the deformation of the stiffening trusses produced by these stresses. This deformation has the effect of reducing the above stress by about 6 per cent. It is, therefore, $\pm$ 301 000 lbs. The cross-section of the chords of the bridge, here considered, is slightly different for the top and bottom chords. It averages 350 sq. ins. at the center of the half span. The stress per square inch, therefore, is $\frac{301\,000}{350} = 860$ lbs. It was found above that the corresponding stress for stiffening trusses 140 and 60 ft. deep, without any center hinges, was $\pm$ 12 110 and $\pm$ 5 190 lbs. per square inch of cross-section.

The stresses in the chords of three-hinged stiffening trusses produced by changes in the length of the cables vary with change in the depth of these trusses in the same ratio as the stresses due to an unequally distributed moving load. The chord sections must vary nearly as the sum of these stresses. The former stresses per square inch of chord section, therefore, are nearly the same, whatever the depth of the three-hinged trusses. For two-hinged stiffening trusses, 60 ft. deep, the stresses due to the change in the elevation of the cables, therefore, are about six times as large as in three-hinged trusses of the same depth.

In stiffening trusses, continuous or fixed at the towers, the temperature stresses are still larger than in those with two hinges. Any disadvantage arising from excessive temperature stresses in two-hinged trusses, therefore, is much increased by the omission of the end hinges.

Wind Stresses in Two-Hinged Suspended Stiffening Trusses.

For estimating the importance and amount of these wind stresses, we take again a span of 2 850 ft. from center to center of towers, with the dip of the cables equal to one-eighth of the span. The stiffening trusses are 60 ft. deep, and have a span of 2 800 ft. between centers of end hinges. The width from center to center of trusses is 92 ft. The wind pressure is 1 600 lbs. per linear foot of bridge. This corresponds to about 30 lbs. per square foot of exposed surface. If the top and bottom chords have equal sections, and if there is a substan-

tial vibration bracing, preventing any considerable deformation of the cross-section, the lateral deflection of the top and bottom lateral systems must be nearly alike. In this case the wind pressures resisted by the two lateral systems are also nearly alike. If the stiffening trusses alone would resist the wind pressure, we would obtain stresses of $\pm 4\,261$ tons at the center of the span in each of the four chords. The cables, however, assist in resisting the wind pressures. To estimate the amount of this assistance, the horizontal deflection must be calculated. For this purpose it is necessary to assume the chord sections of the stiffening trusses and the dead loads. The gross section of the chords of the stiffening trusses will be assumed to be 700 sq. ins. throughout their length. In an actual design these sections would decrease in the end thirds of the span. The bridge here assumed, therefore, will have the same lateral deflection as a bridge with somewhat larger maximum chord section of the stiffening trusses. The dead load for this design is about 38 000 lbs. per linear foot, the moving load is as given before. The wind stresses in the stiffening trusses are largest when the moving load on the cables is small. Those wind stresses in the chords of the stiffening trusses are wanted which occur together with the largest stresses from the moving load. Some of the largest stresses from the moving load occur when the total load, w, on the cables is as little as 42 000 lbs. per linear foot. If the lateral deflection of the trusses at the center of the span is δ, the lateral deflection of the cables is the same amount. If the cables are not cradled, and if the horizontal force acting on them is uniform per linear foot of bridge, then the horizontal projection of the cables is a parabola. The tangents to this parabola at the saddles form angles, α, with the axis of the bridge given by the equation tan. $\alpha = \frac{2\,\delta_1}{\frac{L}{2}} = \frac{4\,\delta_1}{L}$ where δ_1 is the lateral deflection at the center of the span, and L is the span from center to center of towers. The horizontal component of the tension in the cables, which have a dip of one-eighth of the span, is approximately $w\,L$. The lateral pressure on each tower, due to the lateral inclination of the cables in the main span, therefore, is approximately $w\,L\,\frac{4\,\delta_1}{L} = 4\,w\,\delta_1$.

The lateral pressure exerted on the two towers is $8\,w\,\delta_1$. The horizontal pressure, x, per linear foot of bridge on the cables must therefore be $x = \frac{8\,w\,\delta_1}{L}$.

If the horizontal force pushing the cables acts at the center of the span only, the horizontal projection of the cables will consist of two straight lines forming angles, β, with the axis of the bridge. The angle β is given by tan. $\beta = \frac{2\,\delta_2}{L}$, and the horizontal force which, if acting on the cables at the center of the span produces there a lateral deflection of δ_2, is $y = 4\,w\,\delta_2$, or one-half the horizontal force which, uniformly distributed over the length of the span, produces the same lateral deflection of the cables.

The horizontal force acting on the cables is partly the wind pressure on the exposed surface of the cables and on half the surface of the suspenders, partly the horizontal component of the laterally inclined pull of the suspenders. The lateral inclination of the suspenders is small near the ends of the span where they are long. The total lateral pressure on the cables, therefore, is a nearly uniform pressure per linear foot of bridge plus a pressure acting near the center of the span.

The writer will assume, as a sufficient approximation to the facts, that the horizontal wind pressure acting on the cables is 200 lbs. per linear foot of bridge and a pressure acting at the center of the span, large enough to produce, with the uniform pressure, the same lateral deflection as that of the stiffening trusses.

The lateral forces acting on the stiffening trusses are, therefore, a uniform pressure of 1 400 lbs. per linear foot of bridge and a pressure acting against the wind at the center of the span. If the latter is y, the lateral deflection of the cables is obtained from the two equations: $x = \frac{8\,w\,\delta}{L}$, and $y = 4\,w\,\delta_2$; where $x = 200$, $L = 2\,850$, $\delta = \delta_1 + \delta_2$, $w = 42\,000$ lbs.

We obtain $\delta = \frac{2\,850 \times 200}{8 \times 42\,000} + \frac{y}{4 \times 42\,000}$, or

$$\delta = 1.697 + \frac{y}{168\,000}.$$

If we neglect the effect of the deformation of the lateral diagonals and struts we find the lateral deflection of the stiffening trusses from the formula:

$$\delta = \frac{1\,400 \times 2\,800^4}{76.8 \times 30\,000\,000 \times 700 \times 92^2} - \frac{y\,2\,800^3}{48 \times 30\,000\,000 \times 700 \times 92^2}$$

$$\delta = 6.303 - \frac{y}{388\,700}.$$

From the foregoing equations,

$$1.697 + \frac{y}{168\,000} = 6.303 - \frac{y}{388\,700}, \text{ or } 4{,}606 = \frac{y}{168\,000} + \frac{y}{388\,700}$$

From this, $y = 540\,200$ lbs., and $\delta = 4.913$ ft.

The average moment of wind pressure to be resisted by the stiffening trusses, if the cables would not assist in resisting the wind-pressures, would be $\frac{2}{3} \times \frac{1\,600 \times 2\,800^2}{8 \times 2\,000} = 522\,667$ foot-tons.

In consequence of the assistance of the cables in resisting the wind pressure, this average moment is reduced to 362 800 foot-tons; or the average moment from wind pressure in the stiffening trusses is reduced to that which would be produced by a wind pressure of 1 110 lbs. per linear foot of bridge acting on them.

The average shear in the lateral systems is reduced in nearly the same proportion by the assistance of the cables in resisting the wind pressure. For the purpose of making comparative estimates it can be assumed that, of the wind pressure of 1 600 lbs. per linear foot of bridge, 490 lbs. is carried by the cables and only 1 110 lbs. by the two lateral systems of the stiffening trusses.

Wind Stresses in Three-Hinged Suspended Stiffening Trusses.

For a bridge of the great weight of the Hudson River Bridge the center connection between the two half spans of the stiffening trusses ought to be so designed that it is able to transfer shears in a horizontal and vertical direction, but no moments.

In this case each half span acts as an independent span to resist wind pressures. The wind pressures carried by the lateral systems of the stiffening trusses to the center of the span are carried by the cables to the towers. The stiffening trusses, under extreme wind pressures, will deflect considerably at the center of the span. Special provision has to be made in the tracks to avoid a sharp angle in the rails. Designs for the center connection of the stiffening trusses and for the special rails at the center and ends of the main span have been made, submitted to eminent engineers and found satisfactory. The uniform wind pressure carried by the cables is less than in the previous case, say 150 lbs. per linear foot. The trusses are higher, but the cross-sections of their members are very much smaller, and their width is less. The total area exposed to wind pressure, there-

fore, is about the same as with two-hinged shallow trusses. The wind pressure acting on the trusses, therefore, is 1 450 lbs. per linear foot of bridge.

The wind stress in each chord, at the center of the half span, therefore, is $\frac{0.725 \times 1\,400^2}{2 \times 8 \times 92} = \pm 906$ tons.

The average wind stress in the chords is approximately $\pm$ 610 tons. This is 31% of the average wind stress in the chords of two-hinged stiffening trusses.

The average wind stress in the lateral web system is 66% of that with two-hinged trusses.

Moving-Load Stresses in Two-Hinged and Three-Hinged Suspended Stiffening Trusses.

The maximum bending moment due to the moving load (neglecting the effect of the change in the length of the cables) in two-hinged suspended stiffening trusses is $\frac{w l^2}{8}$ 0.1482, and in three-hinged suspended stiffening trusses is $\frac{w l^2}{8}$ 0.1506, where w is the load per linear foot of truss and l is the span. The maximum moments extend over greater lengths of two-hinged than three-hinged trusses.

The average bending moment in two-hinged trusses is $\frac{w l^2}{8}$ 0.113, or 76.25% of the maximum moment. In three-hinged trusses the average bending moment is $\frac{w l^2}{8}$ 0.09744, or 64.7% of the maximum moment. The average moment of three-hinged trusses is only 0.862 of the average moment of two-hinged trusses. These values of the averages are taken from a calculation made by Edwin Duryea, Jr., M. Am. Soc. C. E. The moments were calculated for 50 panel points in the half span. These calculations, however, were made with a moving load of such length as to give the largest stress. They are approximately true for positive moments if the moving load is limited to 1 000 ft. in length. The negative moments will not be used in the calculation of the sections.

As will be shown later, the three-hinged stiffening trusses, 140 ft. deep, must distribute about 12 000 lbs. of 13 600 lbs. of moving load per linear foot of bridge; the remainder is distributed by the cables.

The two-hinged trusses, 60 ft. deep, must distribute only seven-eighths as much, the remainder being distributed by the cables.

The largest chord stress from moving load is 3 170 tons in the three-hinged trusses and 6 296 tons in the two-hinged trusses.

Unit Stresses and Chord Sections in Two-Hinged and Three-Hinged Trusses.

The writer will assume the use of steel of from 80 000 to 90 000 lbs. ultimate strength, and 45 000 lbs. elastic limit, and will calculate the sections by using, of the two opposite maximum stresses, only that one which requires the largest section. The unit stress for tension per square inch of net section will be taken at 22 500 lbs., if wind stresses are omitted, and 20% more if they are added. The unit stress in compression will be taken at $22\,500 - 90\frac{l}{r}$, if wind stresses are omitted, and 20% more if they are added. The reasons for the selection of these values will be given later.

From the preceding investigations we obtain, for two-hinged trusses:

- The largest chord stress from moving load, 6 296 tons;
- The largest chord stress from wind pressure, $4\,261 \times \frac{1110}{1600} = \pm 2\,956$ tons;
- The stress per square inch in the chords, from the change in length of the cables, $\pm$ 5 190 lbs.

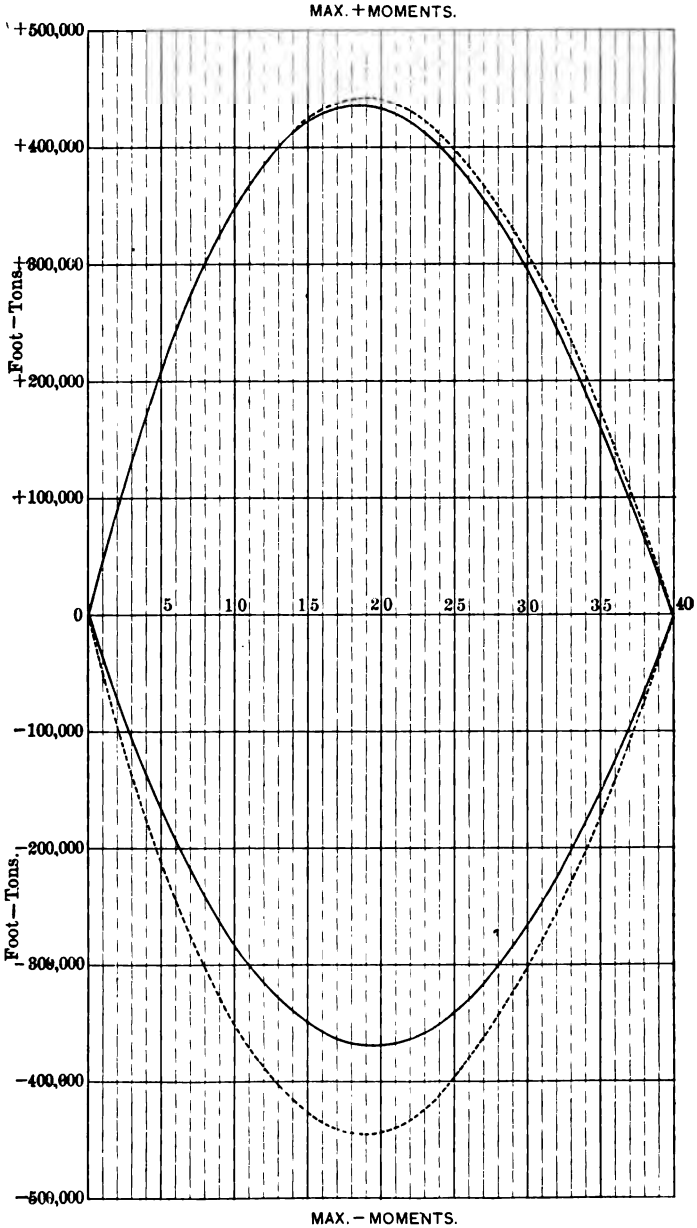
For three-hinged trusses:

- The largest chord stress from moving load, 3 170 tons;
- The largest chord stress from wind pressure, $\pm$ 906 tons;
- The stress per square inch in the chords, from the change in the length of the cables, $\pm$ 860 lbs.

The $\frac{l}{r}$ for two-hinged trusses is 25. The $\frac{l}{r}$ for three-hinged trusses is 30. The net section is seven-eighths of the gross section.

This gives the largest top chord section for two-hinged trusses = 969 sq. ins.; for three-hinged trusses, 356 sq. ins.; the largest bottom chord section for two-hinged trusses, 970 sq. ins.; for three-hinged trusses, 356 sq. ins.

In two-hinged trusses it was found that the average chord stress from moving load is 76.25% of the maximum chord stress.


MAX. + MOMENTS.
+500,000
+400,000
+300,000
+200,000
+100,000
0
−100,000
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Foot – Tons.
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5
10
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30
35
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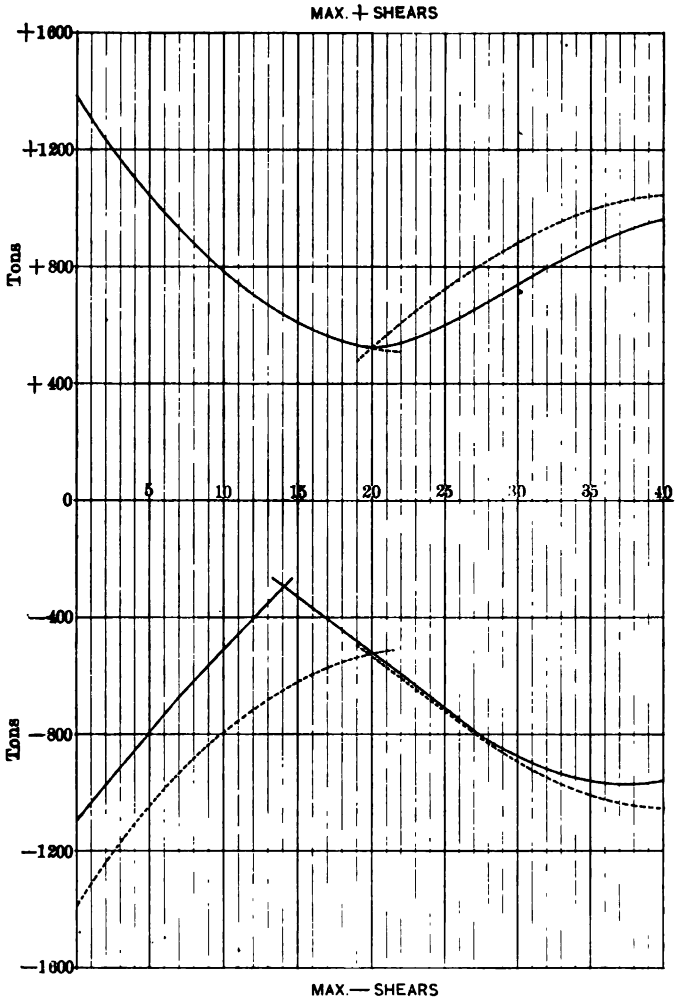
MAX. − MOMENTS.

FIG. 1.



In Figures 1 and 2 the full lines give Maximum Moments and Shears due to a continuous moving Load 1000 ft. or less in length, the dotted lines, those due to an unlimited length. These diagrams, (Figs. 1 and 2) are for a moving load of 3 tons per foot per truss, and for a one-half span of 1400 ft.=40 panels at 35 ft.

FIG. 2.

The average chord stress from wind pressure, according to these assumptions, is two-thirds of the maximum. The average chord stress due to change in length of the cables is three-fourths of the maximum.

The average chord section of two-hinged trusses, therefore, is approximately three-fourths of the maximum chord section, if allowance is made for the unavoidable surplus section near the ends of the span.

For three-hinged trusses the average chord section was obtained from a completed stress sheet, and was found to be three-fourths of the maximum chord section.

The top chords of the three-hinged trusses are slightly longer than those of the two-hinged trusses; allowing for the increase in weight caused thereby by increasing the chord section of the three-hinged trusses, we obtain an average chord section of 727 sq. ins. for the two-hinged, and 268 sq. ins. for the three-hinged, trusses. The difference is 459 sq. ins. Allowing 28% for connections, latticing and rivets, this means that the chords of the two-hinged trusses weigh 8 000 lbs. per linear foot of bridge more than those of the three-hinged trusses.

In this investigation those moments which produce compression in the top chords are called positive moments; those shears which produce tension in the diagonals rising toward the near end of the span are called positive shears.

For a limited length of moving load the positive moments and shears are larger than the negative ones. For three-hinged trusses and an unlimited length of load, the positive and negative moments and shears are alike if two trains are used on each track. But with only one train the negative shears are smaller in some cases. Figs. 1 and 2 give the maximum moments and shears in three-hinged stiffening trusses due to a load 1 000 ft. long, or less, and those due to a load of unlimited length. The calculations were made by Mr. Duryea, who kindly offered them for the writer's use.

Before the webs and laterals of three-hinged and two-hinged trusses can be compared, another investigation is required, which will here be introduced.

Stresses in Lateral Systems Due to Moving Load.

No attention is generally given to these stresses, and experience with ordinary bridges seems to show that no harm results from this

neglect. The proposed Hudson River Bridge, however, is so extremely different, in its general dimensions and in its number of tracks, from ordinary bridges, that it is not safe to conclude that these stresses may be neglected.

The writer will first consider the case of two-hinged stiffening trusses 60 ft. deep. A top and bottom lateral system and a substantial vibration bracing is assumed to be used.

The longitudinal center line will be called the axis of the bridge, and the line perpendicular to it at the center of the span, alone, will be called the center line.

If the tracks south of the axis, and west of the center line, and those north of the axis and east of the center line, are loaded, and the remainder unloaded, the west half of the south truss and the east half of the north truss will bend down, and the other parts of the trusses will bend up.

First, consider the vibration struts as being absent. The moving load on the south truss of the west half span is two-thirds of the maximum moving load of this truss. The moving load on the north truss of the west half is one-third of the maximum moving load of this truss. The moving load on the south truss of the west half span is different from that on the east half span of the same truss by one-third of the maximum moving load per truss. The average stress in the chords is somewhat less than one-third of the maximum average moving-load stress. The maximum stresses from moving load in the chords are 6.5 tons per square inch. The average chord stress under the foregoing loading, therefore, is about 2 tons per square inch.

In the southwest truss there is compression in the top chords and tension in the bottom chords. In the northwest truss there is tension in the top chords, and compression in the bottom chords. The southwest truss, therefore, will deflect downward, the deflection at the quarter being $\delta = \frac{l^2\, t}{4\, \varepsilon\, d}$, where $t = 2$ tons, $\varepsilon = 15\,000$ tons, $d = 60$ ft., and $l = 1\,400$ ft. If these values are introduced we obtain $\delta = 1.09$ ft. The northwest truss will deflect upward an equal amount. If we consider the horizontal trusses formed by the top chords and top laterals and by the bottom chords and bottom laterals, we find that the top truss of the west half span will bend northward, because the north chords expand and the south chords contract; the

bottom truss will bend southward the same amount. The horizontal deflection at the quarter span is $1.09 \times \frac{60}{92} = 0.71$ ft. In Fig. 3 the consequent deformation of the cross-section at the quarter span is shown in dotted lines, but exaggerated.

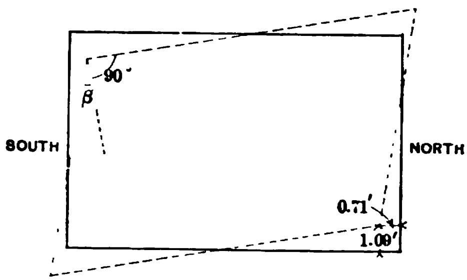


FIG. 3.

The vibration bracing and the rigid vertical posts practically prevent this deformation. By this vibration bracing a part of the weight on the south truss is carried over to the north truss and pulls this down and southward at the top. At the same time it pulls the south truss up and northward at the bottom. If the load per linear foot which is carried to the north truss is q, then the horizontal pull created in both lateral systems is $q \frac{92}{60}$. It will be assumed that the load q is uniform over the length of the half span. The same chords serve for the horizontal and vertical trusses. The loads on the horizontal and vertical trusses are as 92 to 60. The depths are also as 92 to 60. The stresses produced by the horizontal and vertical forces, therefore, are equal, and the total stress in the chords is equal to twice the stress produced by the vertical forces alone.

The vertical deflection of each truss produced by the transference of the load q per linear foot from the south to the north truss, therefore, at the quarters, is $\delta = \frac{2\, q\, l^4}{76.8\, E\, I}$.

The average chord section is 727 sq. ins.; $l = 1\,400$ ft.; $E = 30\,000\,000$ lbs., and $I = 727 \times \frac{60^2}{2}$. If these values are introduced in the formula, then $\delta = \frac{q}{393}$. The deflection of the horizontal trusses, due to the deformation of the chords, is $\delta_1 = \delta \times \frac{60}{92} = \frac{q}{602}$.

The influence of the deformation of the lateral diagonals of the bottom lateral system cannot be neglected, as the stresses produced in them are quite large, and their sections moderate. If the average stress

per square inch of gross section in these laterals, produced by the foregoing distribution of the moving load, is 8 000 lbs., then the horizontal deflection produced by their deformation is 0.38 ft. In the absence of vibration struts, the change in the angle between the vertical posts and the floor beams would be β, where tan. β is approximately given by the equation:

$$\tan. \beta = \frac{1.09 \times 2}{92} + \frac{0.71 \times 2}{60} = 0.04736.$$

This deformation is corrected by the deflections caused by the load q, which is transferred from the south to the north truss. The writer will assume that the deflection caused by the deformation of the web of the top lateral system is the same as that caused by the deformation of the bottom lateral diagonals. The deformation of the floor beams, serving as bottom lateral struts is neglected.

We obtain

$$\tan. \beta = \frac{2 \left\{ \frac{q}{602} + 0.38 \right\}}{60} + \frac{2\,q}{393 \times 92}.$$

If the value of tan. β, thus found, is introduced, $q = 313$. The horizontal force per linear foot acting on each lateral system, therefore, is $313 \times \frac{92}{60} = 480$ lbs.

This pressure acts in one half span in one direction, and in the other half span in the other direction. The stresses produced by this force in the laterals must be added to those produced by wind pressure. The average lateral stresses are increased thereby by about 43 per cent.

If the total tension per square inch, net, in the laterals is made 30 000 lbs., then their stress per square inch, gross, from moving load, is about 8 000 lbs. on an average, as previously assumed. The neglect of these stresses would give dangerously weak laterals near the center of the span. They must also be considered in dimensioning the vertical posts and the vibration struts.

In the three-hinged stiffening trusses, 140 ft. deep at the center of the half span, the lateral pressure in each lateral system is increased on an average about 140 lbs. per linear foot, or 20% of the wind pressures.

The wind stresses in the laterals of the three-hinged trusses were found to be 66% of those in the laterals of the two-hinged trusses.

After making the necessary additions of moving-load stresses it is found that the total stresses in the lateral systems of the three-hinged trusses are $66 \times \frac{120}{143} = 55.4\%$ of those in the lateral systems of the three-hinged trusses.

The laterals and vibration struts of the three-hinged trusses weigh 1 500 lbs., those of the two-hinged trusses weigh 2 000 lbs., per linear foot of bridge.

Comparison of Web Systems of Two-Hinged and Three-Hinged Trusses.

For the calculation of the web systems of two-hinged and three-hinged trusses we have no wind stresses in either. The average shears for two-hinged and three-hinged trusses were calculated by Mr. Duryea by using 50 panels in each half span. The average shear was found to be 1% larger in three-hinged than in two-hinged trusses. The loads were taken of unlimited length. The assistance given by the cables was not taken into account. Allowing for the latter, the average shear will be only seven-eighths as large in the 60-ft. deep two-hinged as in the 140-ft. deep three-hinged trusses. The shears due to changes in the length of the cables are about six times as large in two-hinged as in three-hinged trusses. In the former they are about 5 200 lbs. per square inch. The shears of the three-hinged, but not those of the two-hinged, trusses are partly resisted by the top chords, as the latter are curved in the three-hinged, and straight in the two-hinged, trusses. The bending moments in the vertical posts, due to the transference of loads from one truss to the other for certain positions of the moving load, are about three and one-half times as large in two-hinged as in three-hinged trusses. Everything considered, the weights of the webs of both kinds of trusses are about alike, and are equal to 2 600 lbs. per linear foot of bridge.

The total weight of the three-hinged trusses is 8 800 lbs., that of the two-hinged trusses is 8 500 lbs. more, or 17 300 lbs. per linear foot of bridge. The addition of 8 500 lbs. to the weight of the stiffening trusses, if two-hinged trusses are used, has the effect of increasing the weight of the cables about 1 875 lbs. per linear foot of bridge. The dead load of the bridge with two-hinged shallow stiffening trusses, therefore, is 38 375 lbs. per linear foot of bridge, or about as assumed in these calculations.

The cables cost at least twice as much per pound as structural steel. The use of two-hinged instead of three-hinged trusses adds to the cost of the main span the same amount as the addition of 8 500 + 3 750 = 12 250 lbs. of structural steel per linear foot of bridge. It adds 28.4% to the total load per linear foot of main span, and increases the cost of the rear cables, anchorages, towers and tower foundations in nearly the same proportion.

The design of a suspension bridge requires a double calculation— first, an approximate one, to determine the general dimensions, and then an accurate one, based on the approximate knowledge of the final results. The calculation and comparison here made cannot claim accuracy, and would not be satisfactory for a design to be executed. It is exact enough, however, for this purpose, which is the comparison of different designs, with a view of selecting one of them for the final calculation.

Braced Chains Compared with Suspended Three-Hinged Stiffening Trusses.

There exist a number of short-span suspension bridges with braced chains. The same system has been proposed for a suspension bridge across the Hudson River, in New York City, the links of the chains to be made of steel wires wound around sleeves. The chains perform the function of the cables and of the chords of the stiffening trusses. The moving loads in the present case are little longer than one-third of the span. The same length of moving load produces the maximum tension and the maximum bending stresses in the trusses formed by the braced chains. A different position of the moving load, however, is required to produce the maximum tension and the maximum bending in a large part of these trusses. With suspended stiffening trusses it is necessary to provide in the trusses for the maximum bending produced by any position of the moving load, and in the cables for the maximum tension. With braced chains one must provide only for the largest sum of the bending stress and tension occurring at the same time. Cables have a uniform section throughout, though the stresses increase toward the towers. Chains can be made of variable section to suit the stresses. The chords of the stiffening trusses are made of structural steel. The braced chains here considered are proposed to be made of wire of three to four times the elastic strength of structural steel. The weight of the metal re-

quired to resist the bending stresses, therefore, is much smaller in the latter than in the former.

Braced chains, however, have serious disadvantages. To prevent compression in the chains, hinges must be introduced, at the towers and anchorages, into the trusses formed by the braced chains. On account of the great stresses in the chains, ordinary hinges are impracticable. Toggle joints, therefore, have been proposed. These are very imperfect hinges, leaving large variable moments which increase the sections required in the chains. The breaking up of the cables into links of chains of about 50 ft. horizontal length, and the introduction of four toggle joints add more than one-third to the weight of the metal required for continuous cables of the same average section. All the connections between the links must be made of steel of only one-third to one-fourth of the strength of the wire of the chains. They are, therefore, very heavy.

The four chains would each have a depth of about 12 ft. This necessitates covers of about twice the weight of the covers of continuous cables for a bridge of the same span and capacity. The absence of hinges at the center of the main span and the presence of very imperfect hinges at its ends entail considerable stresses due to the change in length of the chains. Two suspended wind trusses are needed at the level of the two decks of the floor, to stiffen the platforms laterally. If these two trusses are connected by bracing in vertical planes (as has been proposed), so as to form also two vertical trusses, there will arise in them, in consequence of vertical deflections, large bending stresses due to the moving load and the changes of temperature.

An unequally distributed moving load produces in the chains, first, a tension equal to that which would be produced in unbraced cables; second, in one of the chains of each truss a compression, in the other an equal tension, due to a bending moment. The total tensions per square inch in the upper and lower chains, therefore, are different. If the lower truss is of the same depth as the upper one, then the arithmetical sum of the stresses per square inch in its two chords is the same as the difference between the stresses in the upper and lower chains above them. If the lower truss is shallower or deeper than the upper truss the stresses per square inch in it (due to moving load and changes of temperature) are smaller or larger than

those above given, in proportion to the ratio of the heights of the lower and upper trusses.

The stresses per square inch in the lower trusses, produced by the rise and fall of the cables in the main span are the same for the same rise or fall of the braced or unbraced cables. They are proportional to the height of the lower trusses. It is evident that everything is in favor of shallow suspended wind trusses. A depth of 30 ft. from center to center of chords, therefore, should be adopted for these trusses. With the upper floor beams riveted between the posts, this allows sufficient clearance between the upper and lower decks.

Since these trusses serve the purpose of resisting the wind pressures and not the vertical forces, it would be still better to omit the diagonals between the top and bottom chords. In this case, there are no stresses from changes of temperature, and the stresses from moving load are greatly reduced. The weight of the platforms is sufficient to prevent any buckling of the chords in a vertical direction.

The large surface exposed to the wind by the deep chains and by the double set of trusses greatly increases the wind pressures. For each linear foot of bridge there will be about 80 sq. ft. exposed to the wind, giving a wind pressure of 2 400 lbs.

Calculation of the Suspended Wind Trusses.

For determining the amount of wind pressure transferred by the cables to the towers, the total load on the bridge must be known. The wind stresses in these trusses are largest when the load is smallest. But the stresses from moving load in the wind trusses are largest with a full moving load on the ten tracks on which we assumed uneven moving loads. The writer, therefore, will assume a moving load of 7 000 lbs. and a dead load of 33 000 lbs. per linear foot of bridge. This gives a total load of 40 000 lbs. per linear foot of bridge. The dip of the cables will be assumed at one-tenth of the span. There are various reasons why a smaller dip than one-eighth of the span is desirable with braced cables. The comparison of designs with different dips can alone show which is the best. One-tenth of the span is taken mainly because an eminent engineer, who has undoubtedly made many calculations, has chosen this dip for his design for the Hudson River Bridge. In this case the cables carry to the towers a wind pressure which is about uniform per linear foot of bridge. If x is the wind press-

ure per linear foot of bridge carried by the cables, then $x = \frac{8\,H\,\delta}{L}$, where H is the horizontal pull in the cables, L the span, and δ the deflection at the center of the span. If the numerical values for these quantities are introduced into the formula, $x = 140.4\ \delta$.

The wind stress in the chords of the wind trusses will be nearly uniform throughout their length; it will be taken at 23 000 lbs. per square inch of net section in tension, and the same amount, reduced by a column formula, per square inch of gross section in compression. Of the two stresses, only that one which gives the larger section is to be used. The chords are supported every 50 ft. The formula $23\,000 - 92\,\frac{l}{r}$ is used, taking $\frac{l}{r} = 60$. Then the unit stress per square inch of gross section will be 8.75 tons. The lateral deflection of the wind truss, neglecting the effect of the deformation of the diagonals and struts, will be found from the formula, $\delta = \frac{l^2\,t}{4\,\varepsilon\,d}$; where $t = 8.75$ tons, $\varepsilon = 15\,000$ tons, $l = 2\,800$, and $d = 92$ ft. We obtain $\delta = 12.4$ ft. From this, $x = 140.4\ \delta = 1\,740$ lbs. The lateral deflection of this bridge, under the load and wind pressure assumed, therefore, is about 12.4 ft. The cables carry a uniform wind pressure of 1 740 lbs. per linear foot of bridge to the towers. The wind trusses would have to be designed to carry a wind pressure of 660 lbs. per linear foot of bridge, which is to be considered as a moving load. In addition to these wind stresses there are stresses from moving load arising in the same manner as in a bridge with suspended stiffening trusses. These moving-load stresses increase the average shear in the laterals to about the amount that would be produced by a wind pressure of 960 lbs. per linear foot of bridge. The average moment in the chords is increased to about the amount that would be produced by a wind pressure of 810 lbs. per linear foot of bridge. These stresses from the moving load in the wind trusses could be avoided by making the connection of the floor beams with the trusses hinged, as has been done in a recent bridge across the Rhine, in Germany. This, however, would detract from the rigidity of the platform, therefore it will not be adopted here. If the foregoing equivalent pressures be assumed for calculating the weight of the wind trusses, the following is the chord stress in the center of the half span: $\frac{405 \times 2\,800^2}{8 \times 92 \times 2\,000} = \pm\,2\,157$ tons.

If, for all stresses combined, there is taken a unit stress of 27 000 lbs. per square inch, net, in tension, and $27\,000 - 108\,\frac{l}{r}$ in compression, the maximum chord section is 210 sq. ins., gross. The average chord section would be $\frac{2}{3} \times 210 = 140$ sq. ins. If 33% is allowed for connections and surplus section near the ends of the span, the weight of the four chords becomes 2 530 lbs. per linear foot of bridge. Substantial vertical posts, with the upper floor beams riveted between them, would be required to keep the two decks vertically above each other. The laterals, inclusive of these posts, weigh about 970 lbs., and the whole wind trusses 3 500 lbs., per linear foot of bridge. Therefore, we have suspended wind trusses weighing 3 500 lbs., compared with suspended two-hinged stiffening trusses weighing 8 800 lbs., per linear foot of bridge. The floor, with 50-ft. panels, however, would be about 1 000 lbs. per linear foot of bridge heavier than the floor for the 35-ft. panels of a bridge with deep stiffening trusses.

The Stiffening Trusses Formed by the Braced Chains.

The upper stiffening trusses formed by the chains and their bracing, together with the suspenders, must now be compared with the cables and suspenders of a bridge with suspended three-hinged trusses. Before this comparison can be made, some other features of the design must be determined.

The shore spans may be supported either from piers below or from the rear cables. The former arrangement permits the deflection of the tracks to one side of the axis of the bridge immediately beyond the towers. This is necessary if the New York approach near the bridge is located west of Eleventh Avenue. If the shore spans are supported from the rear cables, the suspenders prevent the deflection of the tracks for a considerable distance beyond the towers. To come near to the surface at the terminal station, the New York approach should go some distance north or south before turning east. Land is cheaper west than east of Eleventh Avenue; this consideration may limit the choice between different designs. A bridge with two equal approach spans carried by braced cables would be more beautiful, and, therefore, offers a more interesting theoretical problem, though it may not be practicable. The writer, therefore, will assume two such approach spans, each 1 600 ft. long from the center of each tower

to the face of each anchorage. To avoid excessive bending moments in the braced cables of the approach spans, when either the main span or an approach span alone is loaded, anchored bents will be assumed at the centers of these approach spans. These fix the elevation of the approach spans at their centers, and have the effect that the bending moments in the braced cables of the main and approach spans are of more nearly the same size. The cables can be put on rollers on the towers, or they may be attached to their tops. In the latter case the towers should be of moderate width, otherwise their weight is greatly increased by bending stresses due to changes of temperature and moving load. Broad towers have also the drawback that the span from center to center of towers is thereby increased, as the least clearance between the piers is given by law. Therefore, towers 30 ft. wide at the top and 80 ft. wide at the bottom will be assumed. In this case, the horizontal forces in the direction of the axis of the bridge are very moderate, and, for the purpose of comparison, may be neglected. The attempt to resist horizontal motion of the cables at the tops of the towers by means of broad towers attached to the cables adds much more to the weight of the towers than can be saved in the braced chains. The ends of the wire-link chains will be taken 100 ft. inside the anchorages and 360 ft. below their position at the towers. At the center of the rear spans the cables are 270 ft. lower than at the towers. The formulas derived by Dr. Th. Schäffer for the calculation of braced arches* will be used for calculating the stresses due to changes of temperature. The main difference between the main span of the bridge here considered and an arch is the motion of the ends of the main span of the bridge, while the hinges of an arch bridge are fixed in position. Another difference arises from the larger unit stresses and consequent greater deformations in a suspension bridge.

Change in Position of the Tops of Towers, Due to Changes of Temperature.

It will be assumed that the wire chains are fixed 100 ft. from the face of the anchorage. The exact dimensions of the rear spans and the position of the supports in the anchorages and at the tops of the towers can be given only after a design has been made. For these calculations an ordinary hinge will be assumed 100 ft. from the face

* Published in the "Handbuch der Ingenieurwissenschaften," Zweite Abtheilung.

of the anchorage and on the towers in their center line. The relative position of the important points of the center line of the rear stiffening trusses is given in Fig. 4.

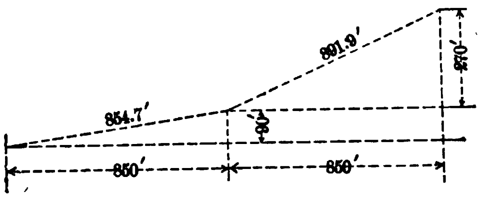


Fig. 4.

It will be assumed that the changes of temperature change the length of the steel members by $\frac{1}{1200}$.

The intermediate bents of the shore spans are oscillating bents, allowing horizontal motion at the top. Their horizontal motion, due to changes of temperature, will be $\frac{854.7}{1200} \times \frac{854.7}{850} = 0.718$ ft. The horizontal motion at the tops of the towers, due to the expansion of the chains between the oscillating bents and the towers, is $\frac{891.9}{1200} \times \frac{891.9}{850} = 0.78$ ft. The total horizontal motion of the tops of the towers, due to the change in length of the rear chains, is 1.498 ft.

The change in the height of the towers produces an opposite horizontal motion. If the steel towers are assumed to extend to 25 ft. above high water, they are about 460 ft. high to the hinge. The opposite horizontal motion at the top of tower, due to the change in height, is $\frac{460}{1200} \times \frac{270}{892} = 0.116$ ft. The total horizontal motion at the top of each tower, due to changes of temperature, therefore, is $1.498 - 0.116 = 1.382$ ft. The change of temperature changes the dip in the main span, and, in consequence, the tension in the chains, and their length; the towers and the suspended arch of the main span offer a resistance against motion of the tops of the towers. All these causes reduce slightly the horizontal motion of the tops of the towers. They will here be neglected.

Temperature Stress at the Center of the Main Span; the Position of the End Hinges Fixed.

The formula giving the stress per square inch at the crown of an arch is

$$\sigma = \pm \frac{15\, E\, \alpha\, t \left((1 \pm \frac{2 f}{h} \right)}{15 + \frac{32 f^2}{h^2}}, \qquad \text{where } E = 28\,000\,000, \qquad \alpha\, t = \frac{1}{2400},$$

$f = 285$ ft., and $h = 60$ ft.

If these values are introduced, $\sigma_1 = \pm 2\ 018$ lbs. and $\sigma_2 = \pm 2\ 493$ lbs. The larger of the two stresses is in the inside chord of the arch. The formula holds approximately for a suspended arch.

Position of End Hinges Moving.—If the distance of the end hinges would change with the changes of temperature in the same proportion as the length of the steel members of the arch there would be no stresses from changes of temperature. The same stresses as those from changes of temperature would be produced by a change in the distance of the hinges by $\frac{1}{1200}$ of the span. This fact enables us to calculate the stresses produced by the expansion of the rear cables. This expansion changes the main span by $2 \times 1.382 = 2.764$ ft. One-twelve hundredth of the main span is 2.375 ft. The stresses produced by the change in length of the rear chains, therefore, are $\frac{2.764}{2.375} = 1.167$ times the temperature stresses, due to the change in length of the chains of the main span. The total temperature stresses, therefore, are $\pm 4\ 367$ and $\pm 5\ 394$ lbs. per square inch. These stresses occur at the center of the span, the larger ones in the upper chain. The results of the calculation are somewhat too large, because some effects of the deformation have been neglected.

The stresses which arise from those changes in the length of the chains which are due to a uniform moving load could be calculated in a similar manner. They amount to about 40% of those due to changes of temperature. This gives the total stresses due to the change in length of the chains by moving loads and changes of temperature of $\pm 6\ 000$ and $\pm 7\ 500$ lbs. per square inch. These results are somewhat larger than the actual stresses with perfect hinges. The imperfection of the hinges, however, will more than balance the slight error in the calculation.

These stresses decrease toward the ends of the main span, and would be zero at the hinges if these were perfect, which, however, is far from the case. The average temperature stress with perfect hinges would be little more than two-thirds of the maximum.

The calculation assumes such an adjustment of the web members of the suspended arches that the stresses here considered are zero at mean temperature and mean load. It is practically impossible to create this adjustment. Any deviation from it gives larger stresses than the

calculated ones. In the formulas used each of the four chains is assumed to have the same section through the whole length of the span, and the same section as each of the other three chains.

It is apparent from the results of the calculation of the stresses due to the change in length of the chains and from the essential similarity of the structures that the bending stresses from moving load in suspended two-hinged arches are approximately the same as in suspended two-hinged stiffening trusses of the same span and depth. For the purpose of a preliminary estimate, it will be assumed that they are the same. If the results show that an exact calculation must be made to determine the preponderance of advantage between this and other designs, the labor of calculating the exact stresses cannot be avoided by those who wish a first-hand knowledge of the subject. If the results show a very great advantage for other designs, this labor may be saved.

Approximate Calculation of the Braced Chains.

It is assumed that the maximum bending stress from moving load in each chain is 6 296 tons, the same as for two-hinged suspended stiffening trusses.

The direct tension in these chains, at the center of the span, is

$$\frac{41\,500 \times 2\,850^2}{8 \times 285 \times 2\,000} = 73\,920 \text{ tons.}$$

The average bending stress in the chains, due to the change in their length, is, at the center of the span, $\frac{1}{2}(6\,000 + 7\,500) = \pm\ 6\,750$ lbs. per square inch. Through the whole span the average is over $\pm\ 4\,500$ lbs. per square inch. The writer will first calculate the section required for the chains to resist the stresses of direct tension and those due to the change in length of the chains. The permissible unit stress in the chains is taken at 35 tons per square inch. The stress due to the change in length of the chains averages 2.25 tons per square inch. This stress, as far as it arises from moving load, does not everywhere coincide with the other maximum stresses due to moving load. To allow for this fact, only $\frac{6}{7}$ of 2.25 tons, or 1.93 tons, will be taken into consideration. This leaves for the direct tension a unit stress of 33.07 tons per square inch. With this unit stress the section required for the four chains at the center of the span is 2 235 sq. ins. At the ends of the span, the section required is 2 408 sq. ins. The average

section required is 2 302 sq. ins. The largest bending stress is 6 296 tons in each chain. To make a low estimate for the weight of the chains, and to allow for the fact that the maximum bending stresses do not everywhere coincide with the other maximum stresses, the average bending stress will be taken at three-eighths of the maximum (in the two-hinged suspended trusses the average bending stress is 76% of the maximum), or $\frac{3}{8} \times 6\,296 = 2\,361$ tons. This, with a unit stress of 35 tons, gives 67.5 sq. ins. for each chain, or 270 sq. ins. for the four chains. The total average section of the four chains, therefore, is $2\,302 + 270 = 2\,572$ sq. ins. Allowing 33% for the weight of the connections, and 4% for the weight of the shell, and considering that the chains of the main span are 2.67% longer than the span, the weight per linear foot of bridge of the chains of the main span is $2\,572 \times \frac{10.2}{3} \times 1.33 \times 1.04 \times 1.0267 = 12\,420$ lbs. Of this weight, 1 304 lbs. per linear foot of bridge is required to resist the last-mentioned bending stresses in the chains. These latter are the only stresses in which there may be a considerable error; they are probably assumed too small, however, rather than too large.

The wire-rope suspenders carrying the platform have larger stresses in this design than in a design with suspended stiffening trusses. In the braced-chain design the suspenders attached to one floor beam must carry the maximum floor-beam load. In the design with suspended stiffening trusses the trusses distribute the load nearly uniformly over the whole span. The load to be carried by the suspenders in the former case is equivalent to 40 000 lbs.; in the latter, it is equivalent to 30 000 lbs. per linear foot of bridge. The allowance for impact must also be larger in the former than in the latter case. The weight of the suspenders with their connections is estimated in the former case at 700 lbs.; in the latter, though the suspenders are longer, at 550 lbs. per linear foot of bridge.

The webs between the chains have stresses similar to those in the webs of two-hinged suspended stiffening trusses. The former, however, must consist of a double system of adjustable tension diagonals, while the latter would consist of riveted members resisting tension and compression. The diagonals of the former must be either soft or medium steel, while the latter can be made of considerably stronger steel with higher unit stresses. The weight of the webs between the

chains is approximately 3 000 lbs. per linear foot of bridge, against 2 600 lbs. for the weight of the webs of two-hinged suspended trusses.

The comparison can now be finished. It has been found that the weight carried by the suspenders is 4 300 lbs. per linear foot of bridge less in the braced-chain design than in the design with three-hinged suspended stiffening trusses. The chains and suspenders in the former design weigh 13 120, in the latter the cables and suspenders weigh 6 600, lbs. per linear foot of bridge. Allowing for the webs between the chains, the former design weighs 13 120 + 3 000 — 6 600 —4 300 = 5 220 lbs. per linear foot of bridge more than the latter.

To fully appreciate the difference between the two designs here considered, the fact must be kept in mind that the cables, suspenders, wire chains and their connections cost about twice as much as other structural steel. This makes the difference between the two designs for the main span equivalent to a difference of 11 740 lbs. of structural steel per linear foot of bridge.

The unit stresses in wire chains or cables and in the structural steel of the stiffening trusses (as far as this is of the same kind) have been taken as the same in all the designs. In view of the practical impossibility of calculating accurately the braced-chain design, and of adjusting it as assumed in the calculations, the unit stresses ought to be taken at least 5% less in this design than in the design with three-hinged suspended trusses, if the same degree of safety is aimed at.

This would make the difference in economy between the two designs still larger.

The calculation of more exact stresses in the braced chains would be a work of months. In view of the great difference in the cost of the designs considered, and of the small error which might be found in the results of this approximate calculation, this work would be an unwarranted waste of labor.

Only the main span has here been considered. Any increase in the weight of the cables will affect the rear spans also. Any increase in the weight of the main span will affect the anchorages, towers and tower foundations.

The advisability of suspending the rear spans from the cables depends so much upon the local circumstances governing the cost of piers that it cannot well be discussed in a general way. An actual

design of the shore spans of the Hudson River Bridge showed a great preponderance of advantage for spans supported from below.

If the rear spans are supported from the cables, the dead load only can be so supported. Most of the moving load coming on the rear span must be carried by it, if the main span is at the same time unloaded. If the whole dead load of the rear spans is carried by the cables, they must be anchored down at both ends, as the moving load on the main span will otherwise lift them up. A rear span equal in length to half the main span will be subject to stresses about twice as large as those in the stiffening trusses of the main span. Therefore, in most cases it becomes advisable to anchor the rear spans by bents near the center, so as to reduce the otherwise excessive stresses. The cases where the rear spans can with advantage be suspended from the cables are very exceptional.

Therefore, in what follows, the writer will give methods for the exact calculation of a suspension bridge with three-hinged, deep stiffening trusses. The rear cables will be assumed to carry only their own weight, the rear spans being supported on piers.

The Calculation of the Stresses from Moving Load, in Three-Hinged Stiffening Trusses.

In the following it will first be assumed that the curve of the cable is, and remains under all circumstances, a parabola, then the tension in the wire-rope suspenders supporting the stiffening trusses, though variable for different kinds of loading, will always be uniform over the whole length of the span. After this, there will be considered separately the modifications produced by the facts; first, that the stiffening truss is flexible and deflects under the influence of moments and shears, which produces a similar deformation of the cables, having the effect that the stresses in the rope suspenders become different throughout the length of the span; second, that the cables change their length under the influence of changing stresses and temperatures, which causes a drop or rise at the center hinge. This has the effect that the curve of the cable, instead of being one parabola, consists of two parabolas which meet at the center hinge at an angle. The cable, instead of having a horizontal tangent at the center, has then two tangents at the center rising or falling against each other. The former of these two cases, which would occur in winter with a

small load on the bridge, if the suspenders in the center could take compression as well as tension, is but slightly modified by the fact that the suspenders are wire ropes.

1. Calculation of Stresses in Stiffening Truss, Neglecting its Elasticity and the Rise or Drop in the Center of the Span.—If a single load, P, at

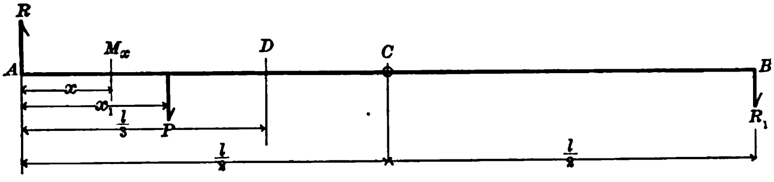


FIG. 5.

the distance, x_1, from the left end of the span (Fig. 5) is applied, the following equations of equilibrium obtain:

1st. The sum of all the vertical forces acting on the truss equals zero.

2d. The moment, in regard to the center hinge, of the forces acting on the left half truss equals zero.

3d. The moment, in regard to the center hinge, of the forces acting on the right half truss equals zero.

If the end reactions due to the load, P, are called R and R_1 (Fig. 5), if the suspender pull per linear foot of bridge produced by the load, P, is p, and if the span is l, we have:

$$R + l\,p - R_1 - P = 0 \qquad (1)$$

$$R_1\,\frac{l}{2} - \frac{p\,l^2}{8} = 0 \qquad (2)$$

$$R\,\frac{l}{2} + \frac{p\,l^2}{8} - P\left(\frac{l}{2} - x\right) = 0 \qquad (3)$$

From these we obtain

$$R = P\left(1 - \frac{3\,x_1}{l}\right) \qquad (4)$$

$$R_1 = \frac{P\,x_1}{l} \qquad (5)$$

$$p = P\,\frac{4\,x_1}{l^2} \qquad (6)$$

The moment at the distance x from the left end is, for $x < x_1$

$$M_x = R\,x + \frac{p\,x^2}{2} = P\,x\left[1 + (2\,x - 3\,l)\,\frac{x_1}{l^2}\right] \qquad (7)$$

From this it follows that a load, P, between A and D (Fig. 5), produces a positive moment at all points between A and D, if $A\,D \overline{\overline{<}} \frac{l}{3}$.

A load located in the third sixth of the span, counting from the left end, produces a moment 0 at a point at the distance x from the left end of the span, if $x_1 = \frac{l^2}{3\,l - 2\,x}$, as follows from Equation (7) by letting $M_x = 0$. At a smaller distance from the end it produces a negative moment, at a larger distance a positive moment. If $x_1 > \frac{l^2}{3\,l - 2\,x}$, then the moment at x is negative; if $x_1 < \frac{l^2}{3\,l - 2\,x}$, then the moment at x is positive.

If $x > x_1$, then $M_x = P\,x_1 \left[\frac{x}{l^2}\,(2\,x - 3\,l) + 1\right]$

This equation indicates that M_x is equal to the ordinate of a parabola which passes the axis of x, for $x = \frac{l}{2}$ and $x = l$.

A force, P, in the left half span produces positive moments between itself and the center of the span, and negative moments in the whole right half span. Fig. 6 gives the moment curves produced by a load, P, in different positions on the span.

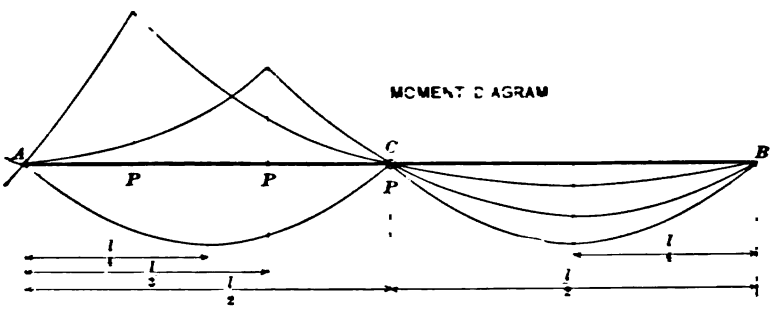


FIG. 6.

Shears.—The shear in a section distant x produced by a load, P, distant x_1 from the left end of the span, where $x < x_1 < \frac{l}{2}$, is $S = R + p\,x$, or $S = P\left[1 + \frac{x_1}{l^3}\,(4\,x - 3\,l)\right]$

This value of S is positive for all x, if $x_1 < \frac{l}{3}$. If $\frac{l}{3} < x_1 < \frac{l}{2}$, then the load, P, produces a shear, 0, at a section distant x from the

left end of the span; when $x_1 = \frac{l^2}{3\,l - 4\,x}$ (1), loads to the left of this produce positive shears at x, loads to the right produce negative shears at x.

If x is larger than x_1 then $S = \frac{P\,x_1}{l^2}(4\,x - 3\,l)$. As long as $x < \frac{3}{4}\,l$ the shear is negative; that is, a load to the left of a section produces negative shears. For $x = \frac{l}{4}$, Equation (1) gives $x_1 = \frac{l}{2}$; for $x = 0$, Equation (1) gives $x_1 = \frac{l}{3}$; that is, while the section, the shear of which is considered, moves from the end to the center of the half span. The load which produces a shear, 0, at this section, moves from a point distant $\frac{l}{3}$ to a point distant $\frac{l}{2}$ from the left end. The shear in the right half span at the distance x from the right end of the span produced by a load distant x_1 from the left end of the span is $S = -\frac{P\,x_1}{l}\left(1 - \frac{4\,x}{l}\right)$. This expression is negative as long as $x < \frac{l}{4}$, and is positive for $x > \frac{l}{4}$. That is, a load in one half span produces negative shears at any point between the outside end and the center of the other half span, and positive shears between the center of the other half span and the center of the bridge.

Fig. 7 gives the shear curves due to a load, P, in different positions on the bridge. Figs. 6 and 7 will assist in determining the positions of the load giving the largest moments and shears.

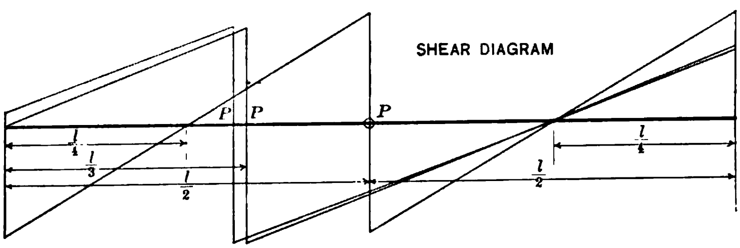


FIG. 7.

In the following derivation of the formulas for maximum moments and shears, a load of 6 000 lbs. per linear foot of truss, not more than 1 000 ft. long, will be assumed.

I. Positive Moments Producing Compression in the Top Chords.—(See Fig. 8.)—To obtain the largest moment at the distance x from the

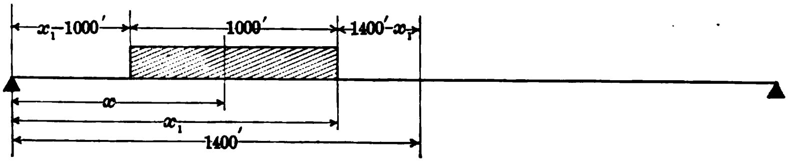


FIG. 8.

left end, the moving load must not cover those parts of the span where it would produce negative moments at x. It may not be long enough, however, to cover the whole of those parts of the span where it does produce positive moments at x. The load is assumed to extend from a point distant x_1 — 1 000 ft. from the left end to a point distant x_1 from the left end, and the moment at the point distant x from the left end is expressed as a function of x_1 and differentiated in regard to x_1 to find the value of x_1, which gives the maximum moment at x. The equations of equilibrium are:

$$2\,800\,p + R - 1\,000\,w - R_1 = 0 \ldots\ldots (8)$$

$$p\,\frac{1\,400^2}{2} + R_1\,1\,400 = 0 \ldots\ldots (9)$$

$$p\,\frac{1\,400^2}{2} + R\,1\,400 - 1\,000\,w\,(1\,900 - x) = 0 \ldots\ldots (10)$$

In which p = suspender pull per linear foot;
w = load per linear foot.

From these we obtain :

$$R_1 = \frac{5\,w}{14}\,(x_1 - 500) \ldots\ldots (11)$$

$$35\,p = \frac{w}{56}\,(x_1 - 500) \ldots\ldots (12)$$

$$R = \frac{w}{28}\,(43\,000 - 30\,x_1) \ldots\ldots (13)$$

$$M = R\,x + \frac{p\,x^2}{2} - (x - x_1 + 1\,000)^2\,\frac{w}{2}$$

$$M_x = w\,x\left[\frac{43\,000}{28} - \frac{15}{14}\,x_1\right]$$
$$+ \frac{w\,x^2}{3920}\,(x_1 - 500) - \frac{w}{2}\,(x - x_1 + 1\,000)^2 \ldots\ldots (14)$$

$\frac{d\,M_x}{d\,x_1} = 0$ gives us $x_1 = 1\,000 + \frac{x}{3920}\,(x - 280)$.

In the foregoing derivation $x_1 - 1\,000$ was assumed as positive. That this may be so, x must be equal to or larger than 280 ft. If we let $x = 35\ \alpha$, where α is the panel index counting from the end, we obtain $\alpha \geqq 8$. If we introduce $35\ \alpha$ instead of x in the foregoing equation for x_1 we obtain

$$x_1 = 1\,000 + \frac{5}{16}\ \alpha\ (\alpha - 8) \ldots\ldots\ldots\ldots\ldots (15)$$

If we introduce this value in Equation (14) and replace x by $35\ \alpha$ w and by 3 tons we obtain :

$$M_x = \frac{15}{4}\ \alpha \left[\ 13\,000 - \frac{150}{16}\ \alpha\ (\alpha - 8)\right]$$
$$+ \frac{15}{16}\ \alpha^2 \left[\ 500 + \frac{5}{16}\ \alpha\ (\alpha - 8)\right]$$
$$- \frac{3}{2}\left[35\ \alpha - \frac{5}{16}\ \alpha\ (\alpha - 8)\right]^2$$

The third line is $= \dfrac{75\ \alpha^2}{512}\ (120 - \alpha)^2$

We obtain by introducing this value and reducing (for $\alpha \geqq 8$).

$$M\ \alpha = 75\ \alpha \left[650 + \frac{\alpha}{16}\left\{100 - \frac{(120 - \alpha)\ (104 + \alpha)}{32}\right\}\right] \ldots (16)$$

We obtain for R, R_1 and p

$$35\ p = \frac{3}{56}\left\{500 + \frac{5}{16}\ \alpha\ (\alpha - 8)\right\} = \frac{15}{896}\left\{1\,600 + \alpha\ (\alpha - 8)\right\} . (17)$$

$$R = \frac{3}{28}\left[13\,000 - \frac{150}{16}\ \alpha\ (\alpha - 8)\right] \ldots\ldots\ldots\ldots\ldots\ldots (18)$$

$$R_1 = \frac{300}{896}\left[1\,600 + \alpha\ (\alpha - 8)\right] \ldots\ldots\ldots\ldots\ldots\ldots (19)$$

For $\alpha < 8$ the load producing maximum positive moments extends from the end of the span to x_1. (See Fig. 9.)

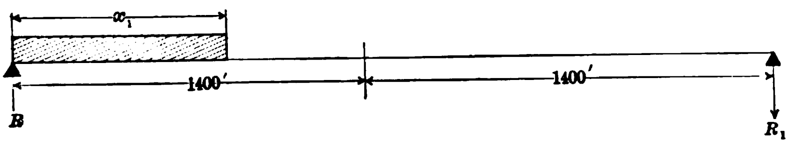


FIG. 9.

The three equations of equilibrium are:

$$2\,800\ p + R - R_1 - w\ x_1 = 0 \ldots\ldots\ldots\ldots\ldots\ldots (20)$$

$$p\ \frac{1\,400^2}{2} - R_1\ 1\,400 = 0 \ldots\ldots\ldots\ldots\ldots\ldots (21)$$

$$p\ \frac{1\,400^2}{2} + R\ 1\,400 - w\ x_1 \left(1\,400 - \frac{x_1}{2}\right) = 0 \ldots\ldots\ldots (22)$$

From these we obtain

$$35\,p = \frac{w\,x_1^2}{80 \times 1\,400} \qquad (23)$$

$$R_1 = \frac{w\,x_1^2}{5\,600} \qquad (24)$$

$$R = w\,x_1\left(1 - \frac{3\,x_1}{5\,600}\right) \qquad (25)$$

$$M_x = R\,x + \frac{p\,x^2}{2} - \frac{w\,x^2}{2} = x\left[R + \frac{x}{2}\left(p - w\right)\right]$$

$$M_x = w\,x\left[x_1 + \frac{x_1^2}{2\,800^2}\left(x - 4\,200\right) - \frac{x}{2}\right] \qquad (26)$$

If we differentiate after x_1 and let $\frac{d\,M\,x}{d\,x_1} = 0$, we obtain

$$x_1 = \frac{40 \times 2\,800}{120 - \alpha} \qquad (27)$$

If we introduce this value of x_1 into Equation (26) we obtain, for $\alpha < 8$:

$$M\,\alpha = 105\,\alpha\left[\frac{40 \times 2\,800}{120 - \alpha} + \frac{1\,600 \times 35}{(120 - \alpha)^2}(\alpha - 120) - \frac{35\,\alpha}{2}\right],$$

$$M\,\alpha = \frac{105\,\alpha}{120 - \alpha}\left[20 \times 2\,800 - \frac{35\,\alpha}{2}(120 - \alpha)\right],$$

$$M\,\alpha = \frac{1\,837.5\,\alpha}{120 - \alpha}\left[3\,200 - 120\,\alpha + \alpha^2\right],$$

$$M\,\alpha = \frac{1\,837.5\,\alpha\,(80 - \alpha)\,(40 - \alpha)}{120 - \alpha} \qquad (28)$$

from (23) and (27) $\quad p = \dfrac{9\,600}{(120 - \alpha)^2} \qquad (29)$

from (25) and (27) $\quad R = \dfrac{336\,000\,(60 - \alpha)}{(120 - \alpha)^2} \qquad (30)$

from (24) and (27) $\quad R_1 = \dfrac{672\,000}{(120 - \alpha)^2} \qquad (31)$

Negative Moments.—(See Fig. 10.)—The equations of equilibrium are

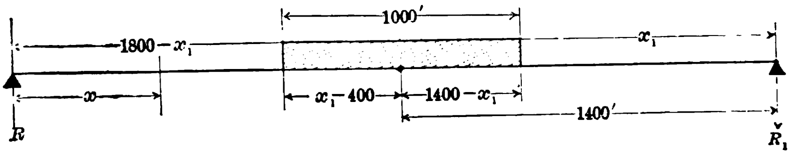


FIG. 10.

$$-R - R_1 + 2\,800\,P - 3\,000 = 0 \qquad (32)$$

$$-R\;1\,400 + \frac{p\,1\,400^2}{2} - \frac{3\,(x_1 - 400)^2}{2} = 0 \qquad (33)$$

$$-R_1\;1\,400 + p\,\frac{1\,400^2}{2} - \frac{3\,(1\,400 - x_1)^2}{2} = 0 \qquad (34)$$

From these we obtain

$$R = \frac{3}{1\,400}\left\{-x_1^2 + 1\,300\,x_1 + 90\,000\right\} \ldots\ldots\ldots\ldots(35)$$

$$R_1 = \frac{3}{1\,400}\left\{-x_1^2 + 2\,300\,x_1 - 810\,000\right\} \ldots\ldots\ldots\ldots(36)$$

$$p = \frac{3}{1\,400^2}\left\{-x_1^2 + 1\,800\,x_1 + 340\,000\right\} \ldots\ldots\ldots\ldots(37)$$

We obtain, therefore, for $M_x = -R\,x + \frac{p\,x^2}{2}$, substituting p and R from Equations (37) and (35),

$$M_x = -\frac{3\,x}{1\,400}\left\{-x_1^2 + 1\,300\,x_1 + 90\,000\right\}$$
$$+\frac{3\,x^2}{2 \times 1\,400^2}\left\{-x_1^2 + 1\,800\,x_1 + 340\,000\right\} \ldots\ldots\ldots(38)$$

Differentiating after x_1 and letting $\frac{d\,M_x}{d\,x_1} = 0$, we obtain, after introducing 35α for x, $x_1 = \frac{100\,(520 - 9\,\alpha)}{80 - \alpha}$ .... (39)

If we introduce this value of x_1 into Equation (38) we obtain,

$$M\alpha = -\frac{3\,\alpha}{40}\left\{-\frac{10\,000\,(520 - 9\,\alpha)^2}{(80 - \alpha)^2} + \frac{130\,000\,(520 - 9\,\alpha)}{80 - \alpha} + 90\,000\right\}$$
$$+\frac{3\,\alpha^2}{2 \times 40^2}\left\{-\frac{10\,000\,(520 - 9\,\alpha)^2}{80 - \alpha)^2} + \frac{180\,000\,(520 - 9\,\alpha)}{80 - \alpha} + 340\,000\right\}$$
$$M\,\alpha = -\frac{75\,\alpha}{8}\left\{720 - 34\,\alpha + \frac{(520 - 9\,\alpha)^2}{80 - \alpha}\right\} \ldots\ldots\ldots\ldots\ldots(40)$$

Introducing x_1 from Equation (39) into Equation (35) we obtain after reduction,

$$R = -\frac{150}{7}\left\{9 + \frac{4\,(520 - 9\,\alpha)\,(130 - \alpha)}{(80 - \alpha)^2}\right\} \ldots\ldots\ldots\ldots\ldots(41)$$

Intrdoucing x_1 from Equation (39) into Equation (37) we obtain, after reduction,

$$p = \frac{3}{196}\left\{34 + \frac{(520 - 9\,\alpha)\,(920 - 9\,\alpha)}{80 - \alpha)^2}\right\} \ldots\ldots\ldots\ldots\ldots(42)$$

Shears.—Positive shears $x < \frac{l}{4}$.

The load extends from x to the right to a point distant $x_1 = \frac{l^2}{3\,l - 4\,x}$ from the left end of the span. (See Fig. 11.)

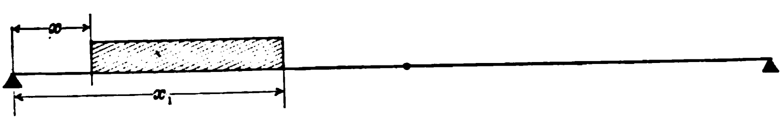


Fig. 11.

The length of the load, $x_1 - x = \frac{l^2 - 3\,l\,x + 4\,x^2}{3\,l - 4\,x}$

The equations of equilibrium are:

$$R + p\,l - R_1 - w\,\frac{l^2 - 3\,l\,x + 4\,x^2}{3\,l - 4\,x} = 0 \quad\text{.......}(43)$$

$$R\,\frac{l}{2} + \frac{p\,l^2}{8} - w\,\frac{l^2 - 3\,l\,x + 4\,x^2}{3\,l - 4\,x} \times \frac{l - x_1 - x}{2} = 0 \quad\text{.......}(44)$$

$$R_1\,\frac{l}{2} - \frac{p\,l^2}{8} = 0 \quad\text{.......}(45)$$

From these we obtain, after introducing $x = 35\,\alpha$, $l = 2\,800$, $w = 3$;

$$R = \frac{21\,(1\,600 - 60\,\alpha + \alpha^2)\,(4\,800 - 340\,\alpha + 3\,\alpha^2)}{32\,(60 - \alpha)^2} \quad\text{.......}(46)$$

$$R_1 = \frac{21\,(1\,600 - 60\,\alpha + \alpha^2)\,(80 - \alpha)\,(20 + \alpha)}{32\,(60 - \alpha)^2} \quad\text{.......}(47)$$

$$p = \frac{3\,(1\,600 - 60\,\alpha + \alpha^2)\,(80 - \alpha)\,(20 + \alpha)}{3\,200\,(60 - \alpha)^2} \quad\text{.......}(48)$$

$$\alpha < 20;\ x < \frac{l}{4}.$$

Positive Shears.— $\alpha > 20$, $x > \frac{l}{4}$. (See Fig. 12.)

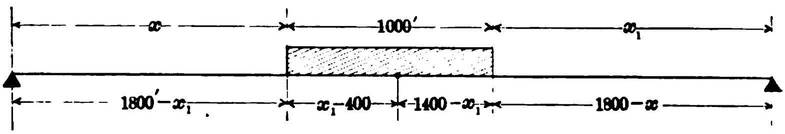


FIG. 12.

For this position of load we found, under the head of negative moments,

$$R = \frac{3}{1\,400}\left\{-x_1^2 + 1\,300\,x_1 + 90\,000\right\}$$

$$p = \frac{3}{1\,400^2}\left\{-x_1^2 + 1\,800\,x_1 + 340\,000\right\}$$

We obtain from this, by introducing for x_1 its equivalent $1\,800 - x$, and letting $x = 35\,\alpha$, after reduction

$$R = \frac{3}{8}\,\alpha\,(460 - 7\,\alpha) - 1735.7$$

$$35\,p = \frac{3}{320}\,\alpha\,(360 - 7\,\alpha) + 18.214$$

$$\alpha > 20.$$

Negative Shears.— $\alpha < 15$. (See Fig. 13.)

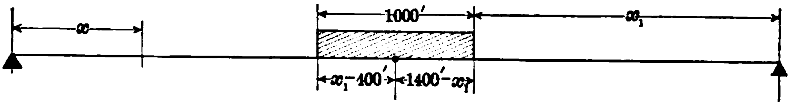


FIG. 13.

We have found previously, for this position of load,

$$R = \frac{3}{1\,400}\left\{-x_1^2 + 1\,300\,x_1 + 90\,000\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(49)$$

$$p = \frac{3}{1\,400^2}\left\{-x_1^2 + 1\,800\,x_1 + 340\,000\right\} \ldots\ldots\ldots\ldots\ldots\ldots(50)$$

$$S_x = -R + p\,x = \frac{3}{1\,400}\left\{+x_1^2 - 1\,300\,x_1 - 90\,000 + \frac{x}{1\,400}\left(-x_1^2 + 1\,800\,x_1 + 340\,000\right)\right\}$$

If we differentiate in regard to x_1, and let $\frac{d\,S\,x_1}{d\,x} = 0$, we obtain, after reduction, $x_1 = 100\,\frac{260 - 9\,\alpha}{40 - \alpha}$. Introducing this value of x_1 in Equations (49) and (50), we obtain

$$R = -\frac{750}{7}\;\frac{9\,\alpha^2 - 820\,\alpha + 16\,400}{(40 - \alpha)^2}$$

$$35\,p = \frac{75}{28}\;\frac{23\,\alpha^2 - 1\,840\,\alpha + 34\,800}{(40 - \alpha)^2}$$

Negative Shears: Second Alternative of Loading.—(See Fig. 14). $15 \leqq \alpha < 29$. For this loading we found previously:

FIG. 14.

$$R = w\,x\left(1 - \frac{3\,x}{5\,600}\right) = 21\,\alpha\,\frac{160 - 3\,\alpha}{32}$$

$$35\,p = \frac{w\,x^2}{80 \times 1\,400} = \frac{21\,\alpha^2}{640}.$$

A numerical calculation shows that this second kind of loading for negative shears gives larger results than the loading above given for $\alpha \geqq 15$.

Negative Shears.—(See Fig. 15.) $x > 1\,000$, $\alpha \geqq 29$. The equations of equilibrium are

$$R + 2\,800\,p - 1\,000\,w - R_1 = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(51)$$

$$R_1\,1\,400 - 1\,400 \times 700\,p = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(52)$$

$$R\;1\,400 - 1\,000\,w\,(1\,900 - x) + p\,1\,400 \times 700 = 0 \ldots\ldots\ldots(53)$$

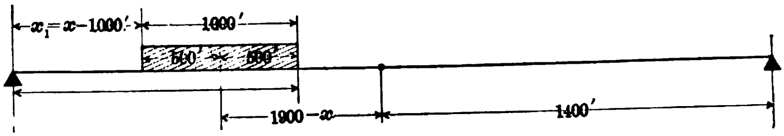


FIG. 15.

From these we obtain $p = \dfrac{3\,(7\,\alpha - 100)}{392}$,

$$35\,p = \frac{15}{16}\,(7\,\alpha - 100), \qquad R = \frac{75}{14}\,[860 - 21\,\alpha].$$

For obtaining the maximum strains in the diagonals, several values of α have sometimes to be tried.

On the Diminution of the Moving-Load Stresses in Stiffening Trusses by their Deformation.

The stiffening trusses will deflect under the influence of the moving load; in consequence, the cables, which are parabolas as long as the stiffening trusses are straight, will change their shape, and the loads per linear foot of bridge carried by them will not be uniform over the whole length of the span. Where the stiffening trusses deflect downward, the load on the cables will be more, and where they deflect upward it will be less, than it would be if the stiffening trusses did not change their form.

For the purpose of obtaining as good an approximation to the actual stresses as is easily practicable, it will be assumed that the loads on the cables are uniform above the moving load 1 000 ft. long and that they are also uniform above the unloaded part of the bridge. The vertical deformation of the cables will be very nearly the same as the vertical deformation of the stiffening trusses below them, as the slight change in length of the suspenders, due to the unequal stresses in them, above the loaded and unloaded part of the bridge may be neglected. To obtain the difference in load on the cables above the loaded and above the unloaded parts of the bridge, we equate the deflection produced in the cables by the difference in the loads on different parts of them, and the deflection of the stiffening trusses produced by their stresses. For the sake of simplicity we determine the deflection of both the cables and the stiffening trusses 700 ft. from the end of the loaded half span of the stiffening trusses, taking the span of the cables to be 2 800 ft. and the deflection one-eighth of the span. We further assume the

moving load 1 000 ft. long to be in the center of the half span. All the dead load, being uniform over the whole span, is carried by the cables, and produces no stress in the stiffening trusses.

In Fig. 16, the dotted curve gives the position of the cables under unequal loading, the full curve that under equal loading. The shaded area gives the load carried by the cables.

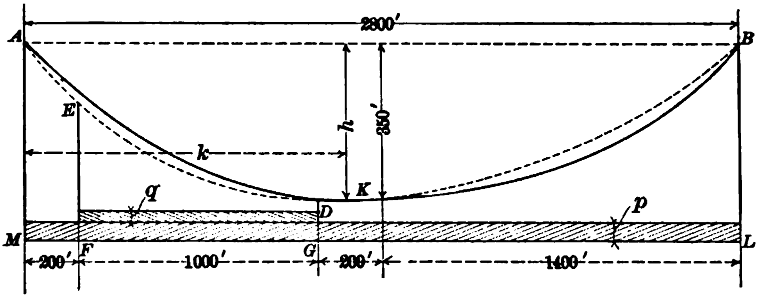


FIG. 16.

If the moving load per linear foot is r, extending from F to G, then we have, in accordance with the above assumptions a uniform load, p, per linear foot of bridge acting on the parts $A\ E$ and $D\ B$ of the cables and a larger load, say, $p + q$ per linear foot of bridge acting on the part $E\ D$ of the cables. On the stiffening trusses we have, on the parts $M\ F$ and $G\ L$, one uniform upward pull per linear foot of bridge, and another uniform downward pull per linear foot of bridge over the part $F\ G$. On this latter part, the upward force from the cables per linear foot of bridge is larger by the amount, q, than on the remainder of the span; the downward force from the loads is larger by the amount, r, per linear foot of bridge than on the remainder of the span. The resultant downward force on $F\ G$ is different from the force acting on the remainder of the stiffening truss by the amount, $r - q$, per linear foot of bridge. If the load per linear foot were the same over the whole length of the cables, then this difference would be r instead of $r - q$. That is, the effect of the difference, q, in the load per linear foot on the different parts of the cables is equivalent to an equal diminution in the moving load acting on the stiffening trusses.

For the purpose of obtaining the change in the deflection of the cables:

Let R = the vertical reaction at the top of the left tower, due to the cables of the main span;

H = the horizontal reaction;

K = the lowest point of the cables;

h = the dip of the cables;

k = the distance of the lowest point of the cables from the left tower.

Then $R = 1\,400\ p + 750\ q$; also, $R = p\ k + 1\,000\ q$; and from these two equations we obtain:

$$k = 1\,400 - 250\ \frac{q}{p};$$

$$\text{also } H\,h_1 = R\ k - \frac{p}{2}\ k^2 - 1\,000\ q\ (k - 700)$$

After introducing the values for R and k from the foregoing equations, we obtain $H = \frac{p}{2\ h}\left(1\,400 + 250\ \frac{q}{p}\right)^2$

The equation of the parabola $E\ D$, with A as origin, $A\ B$ as axis of x, and $A\ M$ as axis of y, is:

$$R\ x - H\ y - \frac{p\ x^2}{2} - \frac{q}{2}(x - 200)^2 = 0.$$

After introducing R and H from the foregoing equations, we obtain for the ordinate y_1 of the point of the parabola, $E\ D$, distant 700 ft. from the left tower:

$$y_1 = h\ \frac{588 + 320\ \frac{q}{p}}{\left(28 + 5\ \frac{q}{p}\right)^2}.$$

If the same amount of load on the cables as above assumed were equally distributed over their length, the dip would be h_1, and the ordinate of the points of the cables 700 ft. from the ends of the span would be $y_2 = \frac{3}{4}\,h_1$.

If h_1 is calculated it is found to be very nearly equal to h, so that the difference, $h - h_1$, may be neglected. The change in the ordinate of the cables 700 ft. from the left tower, therefore, is

$$y_1 - y_2 = h\ \frac{588 - 320\ \frac{q}{p}}{\left(28 + 5\ \frac{b}{p}\right)^2} - \frac{3}{4}\ h.$$

If we let $y_1 - y_2 = \delta$ and $\frac{q}{p} = t$, and find t from the foregoing equation, we obtain

$$t = \frac{55\,h - 140\,\delta - 55\,\sqrt{h\,(h - 9.95\,\delta)}}{18.75\,h + 25\,\delta}$$

δ is the change in the ordinate of the cables 700 ft. from the left tower, due to their unequal loading as compared with equal loading of the same amount. This must be equal to the deflection of the stiffening trusses directly below, caused by the stresses due to the given loading.

This deflection, calculated from a stress sheet of the stiffening trusses, is 2.5 ft., and h is equal to 350 ft. If these values are introduced into the foregoing formula for t, we obtain:

$$t = \frac{q}{p} = 0.05232; \quad \text{or } q = 0.05232\,p.$$

The dead load per linear foot of bridge on each side of the axis is 14 000 lbs., and the corresponding moving load is 6 800 lbs. per linear foot of bridge. The latter is 1 000 ft. long. Since the downward forces acting on each truss are equal to the upward forces acting on it, we have:

$$R + R_1 + 6\,800 \times 1\,000 + 14\,000 \times 2\,800 = q \times 1\,000 + p\,2\,800.$$

The two end reactions R and R_1 of the stiffening trusses are alike and opposite for this kind of loading. After the introduction of the value of q from the previous equation and reduction, the equation, therefore, becomes $p = 16\,128$ lbs.; and, from this and the previous equation, $q = 844$ lbs. The result, therefore, is that the cables on each side of the axis distribute 844 lbs., and each stiffening truss 5 956 lbs. of the total moving load of 6 800 lbs. per linear foot of bridge.

As can be shown by a lengthy argument, which the writer will not introduce here, the assumption made that the loads acting on the cables are uniform over the loaded part of the span, and also uniform but different over its unloaded part is not quite correct. The method here used for finding the part of the moving load which is distributed by the cables, therefore, is approximate only.

In the case of deep stiffening trusses, the diminution of the stresses from moving load, in consequence of the deflection of these trusses, amounts to about one-eighth of the total stress which would exist if the trusses were rigid, or to one-seventh of the stresses obtained in the stiffening trusses. An error of 10% in this correction, therefore,

amounts to only 1.4% of the stress obtained. The method, there fore, may be used for deep trusses without serious error. For very shallow trusses it would be objectionable, as the error there would be a large fraction of the final result. Very shallow trusses, however, can only be used for highway bridges. Center hinges in them are superfluous.

The results here obtained, in regard to the relative economy of three-hinged and two-hinged stiffening trusses and braced chains, apply only to bridges of about the dimensions of the example chosen for the comparison.

The formulas given for the calculation of the moving-load stresses in a stiffening truss of three hinges apply only to a truss of 2 800 ft. span with 80 panels of 35 ft., and with a moving load of 3 tons per foot, 1 000 ft. long or less. The formulas can easily be changed to suit a different number of panels or a different amount of load. The manner of obtaining the formulas is given, and can be applied to any length of span and any length of load.

The formulas given have been repeatedly checked, first by Mr. E. Ludlow Gould, then by Mr. Edwin Duryea, Jr., and by Mr. Alfred Noble. They were used in making the stress sheets repeatedly referred to.

The Proper Unit Stresses in the Stiffening Trusses.

The trusses here considered differ from ordinary trusses, for which the usual unit stresses are appropriate, not only by the unprecedented span, but by other characteristics which have an important bearing on the selection of the unit stresses. All members of these trusses are subject to opposite stresses of nearly equal amounts. The stresses of one kind are the consequence of upward pulls by the suspenders above the unloaded parts, which are in excess of the weights directly below. These stresses reach the trusses in a very indirect way, as they travel from the moving loads by the nearest suspenders into the cables, through these to other suspenders and through them to the unloaded parts of the trusses. The maximum stress of one kind, even in the floor-beam suspenders, is due to the co-operation of loads on at least six tracks. The maximum stress of the other kind is due to a definite position of ten trains of maximum weight. In all other members, except the floor-beam suspenders (which need special unit

stresses), both kinds of stresses only occur by the coincidence of ten trains of maximum weight in a definite position on the bridge. A peculiarity of the stiffening trusses is that any load in the wrong place diminishes the stresses instead of increasing them.

To assist in the judicious selection of the unit stresses the writer will give in figures a rough approximation to the frequency of occurrence of given fractions of the maximum stresses. For this purpose an estimate of the number of trains of maximum weight is required.

The freight trains of 1 500 tons would, if ever, rarely go to the city, and would probably never leave the city. It will be assumed, however, that two such trains will pass each way daily, and 150 trains per day of half this weight on each track.

On the long-distance passenger tracks, it will be assumed that there are on each track 20 daily trains of 750 tons, and 120 daily trains of half the weight.

On the six tracks connected with the elevated and underground roads in New York it will be assumed that there are on each track 60 trains of maximum weight per hour for four hours each day, and 20 trains of half weight per hour for the remainder of the day.

These assumptions are somewhat arbitrary, but, undoubtedly err by excess rather than deficiency. The street-car tracks will have practically uniform loads over the whole span, and need not be considered here.

Each train will produce maximum stresses in any one member only in one position; but it will produce stresses near the maximum in neighboring positions. All trains will produce important stresses of one kind in any given member during about 800 ft. of their motion. A speed of 40 ft. per second will be assumed. Each train, therefore, will produce important stresses during not more than 20 seconds. All the freight trains are assumed to be crowded into 12 hours each day. The two freight tracks are assumed to be in the center between the trusses; the two long-distance passenger tracks are assumed to be on one side, between the freight tracks and the trusses.

There would be one eastward freight train of maximum weight in a position to produce its share of the maximum stress of one kind in any member for less than 40 seconds during each 12 hours, or for $\frac{1}{1080}$ of the total time. There would be two freight trains of maximum

weight in the proper position on the bridge to produce their share of the maximum stress of one kind in any member of the trusses for $\frac{1}{1080^2}$ of the total time. While the former event occurs twice a day, the latter occurs only once in 540 days, or once in 1.48 years. This combination produces less than 44.1% of the maximum stress in the stiffening trusses.

On the long-distance passenger track near one truss there is one train of maximum weight for 400 seconds every 24 hours, or for $\frac{1}{216}$ of the total time. This train produces a stress in the rear truss of less than 18.22% of the maximum stress during this time. It coincides in the proper position with the two freight trains producing 44.1% of the maximum stress less than once in $1.48 \times 216 = 320$ years. The stress due to this coincidence is less than 62% of the maximum stress.

A light passenger train on the other long-distance passenger track is for $\frac{1}{36}$ of the time in the proper position on the bridge to produce a stress not exceeding 9.8% of the maximum stress. A stress of 72% due to this combination occurs less frequently than once in $320 \times 36 = 11\ 520$ years. A heavy suburban train on the track nearest the truss considered occurs during four hours each day for one-third of the time in a position to produce a stress not exceeding 5.5% of the maximum stress. A stress of 77.5% due to the combination of all the preceding trains occurs less than once in $11\ 520 \times 9 = 103\ 680$ years.

If we take heavy freight trains on the two freight tracks and light passenger trains on the passenger tracks near the truss considered, we find that 56% of the maximum stress occurs less than once in 27 years.

If we take the four hours of heavy suburban traffic, we find that there is one train in proper position to produce large stresses for $\frac{1}{3}$ of the time, two trains for $\frac{1}{9}$ of the time, 3 trains for $\frac{1}{27}$ of the time, 4 trains for $\frac{1}{81}$ of the time, 5 trains during $\frac{1}{243}$ of the time, and 6 trains during $\frac{1}{729}$ of the time. The last combination occurs once a day, and it produces 45% of the maximum stress in one of the trusses. The two heavy freight trains coincide during these four hours once in $4\frac{1}{2}$ years. A stress equal to 89% of the maximum occurs less than once in $4.5 \times 729 = 3\ 180$ years. If the heavy passenger train on the track nearer this truss is combined with the last combination we obtain 96% of the maximum stress once in $3\ 180 \times 216 = 687\ 000$ years. The maximum

stress itself, according to the assumptions made, would occur once in 687 000 × 216 = 148 350 000 years. The frequency of occurrence of the various percentages of the maximum stress here given, is evidently much exaggerated as it has been assumed that each train will produce its greatest effect for 20 seconds.

The experiments, which show that by the frequent application of opposite stresses it is possible to break a bar with a much smaller stress than if only one kind of stress is used, therefore, have no bearing on this case. The theoretical maximum stress may occur once in the lifetime of the bridge, but even this is extremely improbable. One is therefore amply justified in dimensioning the stiffening trusses by considering only that maximum stress which requires the larger section. Impact in the main diagonals and chords of this bridge is a practically negligible quantity. The maximum wind stresses are also of rare occurrence, and their coincidence with the maximum moving-load stresses is extremely remote.

The maximum stresses, therefore, may be treated as if they were dead-load stresses of only one kind. For dead-load stresses two-thirds of the elastic limit of test specimens is generally considered a safe stress. The steel in the stiffening trusses has been assumed to have an ultimate strength of 80 000 to 90 000 lbs., and an elastic limit of 45 000 lbs. per square inch. A stress of 30 000 lbs., therefore, would be a safe unit stress, if all the stresses were considered. The weight of the members, and the wind pressure on them, produce bending stresses which were not considered in dimensioning. To allow for these a stress of 27 000 lbs. per square inch, net section, has been used for tension, and $27\,000 - 108\,\frac{l}{r}$ was taken as the unit stress in compression. For moving load alone the corresponding unit stresses were 22 500 and $22\,500 - 90\,\frac{l}{r}$.

For the cables, wires of an ultimate strength of at least 200 000 lbs. and an elastic limit of 170 000 lbs. were assumed. The wire couplings should have at least 95% of the strength of the wires.

If the cables are properly designed, so that the bending stresses in them are of small amount and known with certainty, a unit stress of 70 000 lbs. per square inch is perfectly safe, if the bending stresses are neglected.

Vol. XXVIII. FEBRUARY, 1902. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

MECHANICAL INSTALLATION IN THE MODERN OFFICE BUILDING.

Discussion.*

By Messrs. ROBERT C. CLARKSON, JOHN W. HILL, WILLIAM COPELAND FURBER and CHARLES G. DARRACH.

Mr. Clarkson. ROBERT C. CLARKSON, M. Am. Soc. C. E. (by letter).—The modern office building has been compared to a city or town, and to the human frame, and had the latter been the human body, the simile would have been most apt, for in the human body dwells each being individually, and in that structure each being takes intense interest, devising means to strengthen and repair any inherent or temporary weakness and to keep the same in a complete condition to resist the passing storm or the inevitable decay of time.

The structural engineer has to do with the skeleton or framework upon which the architect rears his flesh and beauty of wall and ornament, but to the consulting mechanical engineer is given the duty of caring for the brain, lungs, heart, veins, muscles and sinews which give to the whole its mechanical life and fit it to man's uses and needs.

It is to the creation and design of the actuating mechanisms that this interesting paper has been devoted, and the writer deems it fitting to add his chapter to the volume.

The surest method of proportioning the amount of boiler power to be provided is to calculate and construct diagrams or "load-lines" of the various machinery, extending them over a range of twenty-four

* Continued from December, 1901, *Proceedings*. See August, 1901, *Proceedings*, for paper on this subject by Charles G. Darrach, M. Am. Soc. C. E.

hours, during the several seasons of the year, to meet the most severe conditions; a combination of the several load-lines, of the machinery to be operated at the same time, giving the maximum power to be generated. The amount of reserve power must be determined by the method of operation, available space, and special conditions to be overcome in each installation. Mr. Clarkson.

The heating plant, no matter how carefully calculated and designed, will often seem to be inadequate during the first winter of operation, the greater portion of its work being the consumption of coal to evaporate the moisture from the walls, floors, etc., due to the necessary use of a great quantity of water, and the soaking of rain, during the course of construction.

Ventilation, although not usually so considered, is one of the most important items of office-building construction. The writer, after twelve years' residence in a building* having ventilation for each office and other room, has just completed a year's residence in an unventilated building.† The presence and operation of the ventilation system in the first building was not particularly noticeable, but its absence in the second building is extremely noticeable, and there is a marked difference in favor of the first building.

The ventilation system should not be made a part of the heating system, neither should the heating of the building be dependent thereon, otherwise it is necessary to operate the ventilating system at all times, whether the building is occupied or vacant, with the consequent wasting of coal due to drawing cold air from out-doors, heating it, and distributing it throughout the building.

The toilet-room ventilation is best accomplished, and the most effective results are obtained, by removing the air from the room through the rear portions of the closet and urinal stalls. This method causes a constant flow of air toward the source of odor, thus preventing its dissemination throughout the general room. The registers also present a neater appearance, with a chance of a larger and more efficient outlet than could be obtained by the method of connecting directly to the china fixtures.

The toilet-room ventilation should be kept entirely separate from the general ventilation of the rooms and hallways, the draught in the main flues and ducts being controlled by separate fans or aspirating coils.

It is necessary to make provision for the maximum operating load for electric lighting and electric power, and this is a variable quantity, dependent upon the liberality of the installation and the particular tenantry of the building. The writer believes that the maximum load of the average installation should be 85% of the installed fixtures.

* Drexel Building, Philadelphia, Pa.

† Stephen Girard Building, Philadelphia, Pa.

Mr. Clarkson. The "proper rating" of an engine and dynamo varies with the viewpoint of the several parties interested in the machinery, and the consulting engineer must determine, from the conditions to be met, the particular sizes and number of units most advantageous to the installation. It is obvious that machinery working ordinarily to its maximum capacity cannot carry 25 and 50% overload, and machinery to meet such additional calls must be installed, under ordinary conditions, to operate that much below the maximum output. If, however, the "proper rating" is taken as the point of greatest economy of the engine, and the heating limit of the dynamo is kept within the range of 35° Cent. above the surrounding atmosphere, the conditions of 25 and 50% overload for varying periods can be taken care of without undue waste in operation or risk of damage to the machinery.

The conveying and disposing of sewage from fixtures below the sewer level can be accomplished with less risk of stoppage, and more ease of operation, if the motive force is compressed air applied directly to the vessel holding the mass to be disposed of, rather than by the use of a pump operating from a tank. By the use of compressed air the working parts exposed to corrosion and clogging are reduced to a minimum, and the operation of the machinery is cleanly, and with facility for repairs.

The matter of fire-protection is a problem also contingent upon the uses and tenantry of the building. The installation of fire-extinguishers is not always to be recommended, for, in many instances, they are allowed to become neglected and inoperative, while, at best, few persons are aware of the nature and proper use of such appliances. If fire-extinguishers are installed, they should be given frequent attention as to fittings and contents, and they should be accompanied by directions as to their proper use printed in bold letters.

The installation of a vertical fire-pipe, with hose at each story, is the usual method of fire-protection, but this is seldom erected with complete facilities. The top of the line should be connected to a tank at the highest point of the building, in such a manner that the line is at all times filled with water, and the bottom of the line should be connected to the largest pump or to a special fire-pump in the machinery room, with a side connection, outside the building, for the connection of the apparatus of the city fire department. With proper signaling apparatus from each hose outlet directly to the location of the pump, and the introduction of the necessary check-valves, the fire-line should be always ready for instant service, with a possible supply from three sources, varying as to the extent of the fire.

The use of automatic hose-reels, or those in which the revolving of the reel opens the valve and turns on the water supply, is not to be recommended. More damage can result from the uncontrolled water than the fire can accomplish in the few seconds necessary to turn a

hand-valve. The use of sprinklers in office buildings is also inadvisable, for the same reason, Mr. Clarkson.

The most effective fire-protection is careful watchmen, with regular fire-drill of all employees.

The elevator service should be considered as a vertical street car system, the hatchways and guides corresponding to the streets and rails; and the operation of the cars must be considered upon similar lines. It would be manifestly impossible to operate a street railway with any degree of efficiency and carrying capacity, if the cars were expected to run at such speed and under such control that a stop was possible every 12 ft., yet this is expected of an elevator service where the cars stop at each floor.

The problem may be solved by dividing the building horizontally into sections, and providing for each section cars of such size and number as will accommodate the average maximum number of passengers from each, with the addition of two or more cars to stop at all floors of all sections.

The use of such an arrangement requires a certain education of the public, but, with the tenants as guides, the outside public soon learns the special arrangement of each particular building.

The elevator cars and enclosures should be arranged to give the greatest facility of loading and unloading. This is best accomplished by double gates, opening the whole width of the car, and by the use of signalling apparatus directing the operator when two or more stories away from a desired stop. If mechanism is introduced to operate the doors, it should be controlled separately from the mechanism controlling the movement of the car, and the equipping of doors and gates with devices to prevent the starting of the car until the gates are firmly closed and fastened should be insisted upon.

The area of the cars should not be less than 5½ by 5 ft. and the maximum speed should not exceed 500 ft. per minute, for the safety devices must be set to operate at a speed greater than that of ordinary running, and at a running speed of over 500 ft. per minute the car will acquire too much momentum before the devices are brought into action, which may result in serious damage, even though all known safety devices are in use; this is particularly the case if the operator should lose control of the car near the bottom of the hatchway, unless the hatchway is fitted with an air-cushion.

The question of motive power for the elevator system admits of many varying answers, and the condition of operation is an important factor in reaching a conclusion as to the most advantageous power. With hydraulic power, the question resolves itself into the method to be used.

One of the smoothest running forms of hydraulic elevator is that of the direct ram or plunger type, which, though there are limits to

Mr. Clarkson. its use, is available for heights of 200 ft. and speeds up to 600 ft. per minute. This form of elevator combines safety, with economy of operation and repairs, and minimum space occupied.

Another type of hydraulic elevator is the vertical cylinder, which is smooth running, and economical in space, but care must be taken to provide means to remove the accumulations of air from the cylinder, otherwise the car will rebound at each stop.

The type of hydraulic elevator probably in greatest use is that with a horizontal cylinder, and while not economical in floor space, it has many advantages to commend its use, its capacity being limited only by the length of the cables obtainable and the ability to construct cylinders of the desired length. With this form of elevator care must be taken to provide means to support the long horizontal cables when the piston is at its maximum extension, otherwise the car will rebound if suddenly stopped.

Where the conditions are such that the use of hydraulic power is impossible, the electric elevator is available; but the electric elevator requires constant attention, and successful operation depends upon the contact of many hundred small wires, any one of which may become loose and disable the apparatus.

If electric power is more accessible than steam, the combination of an electrically driven pump with a hydraulic elevator makes an installation economical in operation and combining the economy of electric power with the simplicity of the hydraulic cylinder.

Other items of lesser importance, such as distribution of cooled drinking water, filters, telegraph and telephone communication, time distribution, watchman's clocks, etc., vary so much that they must be solved to suit each structure, and are not amenable to any fixed rules.

In all the foregoing it is supposed that the architect will co-operate with the engineer, and provide ample space for the installation of all necessary machinery, and that the owner will provide a sufficient number of skilled attendants to operate and care for the apparatus. Many times, however, does every engineer find that he must, to save his reputation, either antagonize the architect, to obtain sufficient space, or the owner, to obtain permission to install machinery of sufficient size and construction, or is forced to abandon the work entirely; every foot of space devoted to machinery, ventilating flues, etc., being deemed as so much loss to the money-earning value of the building.

Mr. Hill. JOHN W. HILL, M. Am. Soc. C. E. (by letter).—This paper and the discussions contain enough matter to show that the mechanics of the modern office building are sufficient to constitute an art, and require for their proper treatment the aid of a specialist in this line of mechanical engineering. With reference to the steam heating of the tall office building, several factors seem to require consideration:

(1) The volume or cubical contents of the building. Mr. Hill.

(2) The exposure of dead wall surface and glazed apertures.

(3) The ceiling height of stories.

(4) The construction of dead wall (whether solid or with defined air-spaces).

The minimum temperature of the atmosphere for a given locality, and the maximum velocity of winds to be considered, must also enter into any formula which undertakes to provide mathematics for the steam or other methods of heating.

The influence of light-wells and elevator shafts in forming an up-cast, and of leaks around door and window frames and sash withdrawing warm air from the surrounding rooms, must have an effect on the cost of heating, although the ventilation thus afforded should be considered as an advantage to the occupants of the building.

The indirect system of heating, *viz.*, by drawing fresh air from the outside of each room or floor around the steam radiators distributing the warm air through the rooms and withdrawing it through ventilating pipes or ducts, has the advantage of frequent change of the air inspired by the tenants, but in the matter of coal charges will usually be the most expensive system of heating to maintain. There is no good reason why this system cannot be successfully operated, but the cost of introduction and operation doubtless opposes its more extensive use in modern public buildings.

High fuel economy cannot be expected in the power required to operate the elevators, when, within a few seconds, the loads vary from no load at all to a maximum; but some system which will admit of storing energy during the periods of low work, to be given out during periods of high work, by storage batteries, water tanks or air receivers, should give the best economy, although such systems will not be adapted to handle rapidly heavy loads quickly repeated. Hydraulic elevators, arranged to consume water in proportion to the load handled and the distance traveled, should represent the least unavoidable loss between the development and application of power. Whether such elevators have been reduced to practice the writer does not know, but efforts in this direction were made more than twenty years ago. Such a system, if supplied from the city mains, should be an economical elevator power, provided the water rents are moderate. Electric elevators supplied from "commercial" currents are economical in consumption of power, and should consume current approximately in proportion to the load handled and the distance traveled. Local conditions must control in each case, and no rule of universal application can be laid down for the source of elevator power. The fact that an electric current is needed for illuminating the modern office building, and that this current can usually be supplied more cheaply in the building than by connection with "commercial" cur-

Mr. Hill. rents suggests the further development of the electric system to provide power for the operation of the elevators and other motion machinery in the building.

There are one or two features of the modern office building, not of an engineering nature, which possess interest alike to the investors and patrons of such structures, *viz.*, the financial returns upon investments in such enterprises, and the economies and advantages to the occupants.

While the financial returns must necessarily vary with the value of ground and improvements, and the location, and with the character of the business conducted by the tenants, still it has happened that thus far such buildings are promptly and steadily tenanted by people who rarely default in their rents; and, upon the assumption that the owners have proportioned the rents to the gross investment and maintenance charges, it is fair to believe that such buildings are usually profitable sources of investment. At the same time it would be of general interest to compare two columns of figures, one containing the interest, and other fixed charges due to the invested capital, and the operating and maintenance charges, and the other the gross income from rents. Some of these buildings, as is well known, have cost more to construct than certain prosperous short lines of railway, and many of them have been built by syndicates or corporations organized in quite the same manner as railway corporations.

The fact that such buildings find tenants, even before they are ready for use, suggests that the tenants find the use of such buildings profitable, or are willing to pay for the extra comforts and conveniences which they afford.

Contrasting the old-fashioned office quarters, with their poor light and heat, and their generally uninviting appearance, with the modern conditions, suggests that, aside from the contracted space which is now often made to answer for formerly large rooms, there are advantages to tenants for which they are willing to pay, and for which some benefits are received or expected.

The general construction and finish of the rooms in the modern office building enable the tenants to dispense with certain accessories of the old-style quarters which represent some gain and much comfort. Steam heat, lavatories, vaults, telephones, mail chutes and elevators save money or time, and their maintenance by the owners of the property relieves the tenant of much annoyance and labor which was his under the old system.

In some respects there is a strong resemblance between the modern office building and a Pullman sleeper. In both, the floor space is more contracted than one desires, but this inconvenience is partly, if not wholly, offset by the conveniences which accompany each. In both, the effort is made to satisfy all the usual and probable requirements of the occupants with the least sacrifice of time and space.

The assembling in the modern office building of many businesses of like kinds promises a distinct advantage to both the user of the building and his patrons. Thus, "The Rookery," in Chicago, for example, contains a collection of offices largely interested in the production or use of iron, steel and similar materials, and of industries akin to these. Mr. Hill.

Two things, however, contribute essentially to the commercial success of the building; the high-speed elevator and the telephone. Indeed, the elevator is the germ from which the sky-scrapers have sprung; without the elevator such buildings would be impossible; and, as the needle with an eye in the point is the feature of the sewing machine, so likewise the modern high-speed elevator may be said to provide the commercial foundation for the modern office building.

The writer's experience with modern office buildings has been that of a tenant, and, from this point of view, it is surprising with how little space one can conduct his work when he has to, and how much of the litter about an engineer's office can be neatly and compactly stowed away and held for future reference if space is cramped. The evolution in business conveniences is not limited to the well-lighted and well-heated office building, with high-speed elevators making the upper floors almost as desirable as those lower down, but is carried into the necessary furniture of such buildings. Compactness and directness characterize all steps taken to develop and furnish the modern office, and this underlying principle doubtless has its effect on the mental faculties of the occupant, in suggesting the same use and application of his time and energies as it does of the space and conveniences at hand.

William Copeland Furber, M. Am. Soc. C. E. (by letter).—Some of Mr. Bolton's remarks indicate that he recognizes, what other keen observers have already recognized, that the high, steel-skeleton office or hotel building is not simply an architectural problem, but a problem in which the architectural treatment is but one of the co-ordinate parts of the design. Mr. Furber.

The architectural treatment is not and should not be considered as the controlling factor—though it generally is—in the design of this modern embodiment of concentrated facilities for administrative business or communistic living.

In buildings of this character a very little thought will be required to perceive that the architectural design is not the controlling factor, and therefore should not be allowed to fix the conditions, to which all other parts of the design should conform. To illustrate this idea: The architectural design can be changed, almost an infinite number of times, without the mechanical engineering essentials being changed at all, and with only such changes in the structural design as may be required locally by the changed architectural disposition of

Mr. Furber. the materials composing the walls, etc. If the truth of this proposition is recognized, it is evident that no extended argument is required to show that the present method is wrong, in putting in the hands of the individual designer of the façade the final decision on all matters of design; and the truth of this proposition can be admitted and acted upon without in any way belittling or making light of the architectural problems, which are of great importance, and should only be entrusted to broad minds and capable hands. For as long as appearances continue to be a factor in human affairs, and as long as beauty of line and form appeal to our sense of intellectual fitness, just so long will the architectural problem be worthy of the most careful consideration.

The recognition of the fact that the architectural part of high-building construction is not the governing factor gives no excuse for slighting this part of the design, but it should be also recognized that the architectural problem, in its specific relation to high-building construction, can be worked out to a rational solution only when the limits which bound it are defined by the factors which actually should control the design as a whole. High steel-skeleton building construction may be defined as an engineering work with an architectural accompaniment.

It is perhaps already evident that in order that each of the elements entering into the design as a whole be given proper recognition, and its due value as a factor, the chief designer should be a man capable of judiciously passing upon the claims of each of these elements to precedence. Experience has shown that the man who owes his training exclusively to the Art School and its influences cannot or will not consider the engineering side of the problem. The men who spell their art with a capital A deplore Science, as a necessary evil, which disturbs their mental repose; and, if not as an evil, then as a bore, which interferes with and places practical obstacles in the way of their flights of fancy. Mathematics and Science are looked upon by men of this type as matters of formulas, rule-of-thumb and mechanical routine, a matter to be learned out of a book, which can be mastered in about the same way that one learns to recite a piece of verse or prose, or as one learns a trade. Men of this type do not think that imagination enters into the study or practice of science, and particularly the science of engineering, and look upon themselves as the only rightful possessors of the wings of flight or imagination. They have no conception of the trained imagination required to comprehend the higher mathematics, nor of the sustained and logical derivatives of the product of thought, obtained from mathematical investigation. Having no appreciation of the intellectual basis of engineering, it is not to be wondered at that they treat the demands of Science with scant consideration. It is, therefore, hardly to be expected that the graduate of the Art School

only whose whole mental training has been given up to the study alone of the relative values in the play of light and shadow, the balancing of solids and openings, the study of the appearances of things, or the art of seeming, can be qualified to pass upon problems which deal with realities or with things as they are. In works of magnitude, under the guidance of such minds, the structural and mechanical parts of the design are often sacrificed to supposed requirements of Art; and the result is an incongruous composite of the total elements of the design, and, necessarily, a failure. Mr. Furber.

Another type of mind which is unsuited for the position of designer-in-chief is that type which has no appreciation of art and beauty, and has no other "measures" than those of "economy" and "efficiency." This type, while useful in a large way as a counterweight and a standard of comparison, often misses the best solution, or possibly never attains it, in a problem of this character, by the narrow view it takes of the things with which it is not familiar, and, by reason of one-sided training, is not fitted to be an intelligent and impartial judge of the various elements entering into a composite and complex design.

The designer best qualified for this important position of designer-in-chief is evidently one who has a knowledge of the broad essentials and limitations of the various parts of the design, the judicial temperament permitting the balancing of an advantage against a disadvantage, a breadth of mind enabling a comprehensive view to be taken, coupled with courage and decision; with all these qualifications, governed by a broad and catholic love of beauty in all its manifestations—not only of beauty of form and line, which is evident and can readily be comprehended, but of the more subtle beauty of Science and its results.

This combination of qualities is not an impossible one, or, in fact, necessarily a very rare one. It is realized, perhaps, more definitely in the scholarly engineer, whose acquaintanceship with facts and laws governing matter is accompanied with a broad knowledge of the fundamental requirements of Art, and to him must eventually come the position of Master Builder.

If the composite design of one of these engineering-architectural problems is analyzed, it will be seen to admit of two main subdivisions:

(1) The engineering design;

(2) The architectural design.

The engineering design can be subdivided into its structural and mechanical components: The structural component, comprising the foundations and superstructure, including the stability of the structure against vibration, wind forces, fire and corrosion. Under the head of structural design should also come the planning of the floor

Mr. Furber. areas and spaces, with all their subdivisions. Usually, the floor plan is laid out by the architectural designer without reference to the structural design, and this results frequently in poor and expensive construction. The consideration of the floor plans and the structural design should take place at the same time—and preferably by the same mind, or at any rate by minds working in harmony, for the floor plan and the structural arrangement are truly dependent on each other. The arrangement of the floor is not strictly an architectural problem, though it is frequently considered as such; it is also a scientific one, or one in which all the factors can be determined and balanced one against the other, and an equation arrived at figuratively, from which a result can be obtained which rests upon determined facts, and not upon mere whim, prejudice or predilection. Daylight has a certain carrying and distributing power which does or should determine some of the dimensions of rooms.

Transportation facilities and convenience of access determine the local arrangement of the office areas around the elevators, or rather the location of the elevators with reference to the "center of gravity" of the office areas. The economic location of lavatory fixtures requires the grouping of these fixtures around common drainage and water supply centers, which in turn demand certain broad arrangements of lavatory rooms and fixtures, usually not difficult to comply with.

The lighting and heating systems require distributive local centers, and sub-centers, which should bear certain relations to the groups of offices and sources of supply.

Not infrequently, the floor plan is decided upon and then turned over to the structural designer with instructions that nothing can be changed. This results sometimes in the use of structural expedients which are expensive and structurally unsatisfactory, and which could have been avoided by an appreciation of the relative values of each of these matters. The consideration of the scheme, also, from one standpoint only, often results in the sacrifice of the best arrangement of the mechanical equipment.

When the planning of the floors and the structural design is under discussion the fire-proofing and rust-proofing should also be considered. It is not an uncommon thing to find the fire-proof covering cut away to get in a door or window frame, or some piping that has been overlooked or not considered when the planning was under consideration, and for this there is no excuse, unless haste in preparing the plans —due to no fault of the designer—is given.

Fire-proofing is generally given but scant consideration, and rust-proofing little, if any, and for this neglect no adequate excuse can be given. The fire-proofing is seldom considered as a part of the design, but is taken care of by general methods of allowances over the dimensions of the beams, girders and columns. The intelligent designing

of fire-proofing demands a knowledge of the weakening effects of heat on steelwork. The maximum strength of iron is at about 400° Fahr., and there is a loss of strength of about 1 000 lbs. per square inch of section for every increase of 100° in temperature. A knowledge of the rate of transmission of heat through various substances and dead air spaces, and a knowledge of the resistances of various materials to the action of fire and water, separately and alternately—a little knowledge of these various matters—will be sufficient to show the insufficiency of many of the present methods, and the inadequacy of many of the materials used for this purpose. Porous or semi-porous terra-cotta properly made and burned is probably the best material in use, but, as it is manufactured to-day, it is too thin, and the standard beam coverings, with a thickness of only 1 in. over the lower flanges of the beams, are absurd, and the column coverings and the methods of fastening them on the steelwork are but little better. Mr. Furber.

The question of rust-proofing is seldom considered, and is often entirely ignored. The rusting of iron is such a familiar fact that it is surprising how little attention is paid to it. Millions of dollars are being invested yearly in buildings the durability and stability of which are entirely dependent upon the iron framework, yet, beyond giving the metal-work a coat of paint, nothing is done. The fact that Portland cement preserves iron from corrosion is now well known, and the chemistry behind this fact should be as well known. Rust is caused by three factors working together, *viz.*, water, an acid, and oxygen. If these three factors are not allowed to act co-ordinately, rusting cannot take place. Portland cement, because it is a product of lime, furnishes a base which neutralizes any acid likely to be present under ordinary conditions, and therefore any water which may filter through it can do no harm. This fact is acted upon in the use of steel in the foundations of buildings below the water line, but little use is made of the knowledge above the cellar floor.

The mechanical component of the engineering design, comprising the steam power plant for operating the elevators, the lighting, heating and ventilation systems, and the layout of each of these parts; the lighting system, consisting of dynamos, distributive wiring and storage battery; the heating system, consisting of the distributive piping, etc., with the fans and ducts required to supply the heat and air under pressure, and to remove the foul air; the operating mechanism of the elevators; the water supply for individual and general uses and fire-protection; the drainage system, and the telephone and telegraph wire systems; should all be considered and tentatively laid out before the final plans are decided upon.

The requirements of each of these subdivisions of the mechanical design require most careful study, and, as they are a vital part of the design as a whole, they should be laid out to accomplish the best

Mr. Furber. possible results, and this arrangement adhered to as closely as is permissible with reference to other parts of the scheme. Most of the evils of crowded and unsatisfactory layouts of the mechanical equipments in high buildings are the result of lack of knowledge, on the part of the designer-in-chief, of the conditions of arrangement conducive to the best results. The fact that the equipment can be placed and operated in inconvenient and contracted spaces is also taken advantage of, and the mechanical equipment relegated to such spaces as can be devoted to no other purposes. When the amount of money required to maintain and operate this equipment, and its proportion to the total operating expenses of the building, is considered, no defence can be made of the inadequate facilities usually allowed for its installation.

In the distributive systems of the mechanical plant, the placing of pipes, conduits, etc., in the floors, walls and partitions is frequently not considered in the detail drawings, and is generally merely specified. This neglect sometimes leads to a great deal of trouble and often to the adoption of make-shift methods, which could have been avoided by due consideration being given to the details on the drawings.

The architectural design consists in the main of the treatment of the façade, usually according to, or with the details of, some historic style; the arrangement of the windows, and, in a secondary way, the architectural treatment of the offices: This internal treatment of offices can be said to be independent of the general architectural structural and mechanical design, and therefore not a factor in the design of the whole, with which only this particular discussion deals.

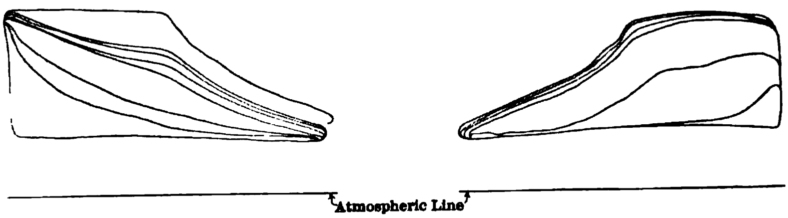
The architectural part of the design can be changed according to the whim or predilection of the designer without materially affecting the other parts of the design. It is therefore evident that with this liberty goes great responsibility. If the design decided upon is one of a possible thousand, and the design is a poor one, the responsibility is proportional to the number of better ways of solving the problem.

A great mistake that many architectural designers make in treating the high skeleton building is in attempting to treat it as a masonry structure. This lack of perception of the limitations of masonry construction leads them to many curious anomalies and absurd results, as, for instance, the placing of a Greek temple on top of a many-storied building, and the employment of brackets, consoles, modillions and other architectural details which once had some function, but which are now, in these buildings, wired or strapped upon an iron framework.

The high skeleton building is worthy of an architectural style consistent with its serious purposes and the dignity of its place in the modern business world, and this style should express the truth

of its construction and its purposes, and should not make it masquerade in borrowed clothing, pretending to be a masonry structure, yet violating some of the fundamental principles of masonry construction. Architecture needs the stimulus of new truth and new conditions, and the skeleton building furnishes them. Mr. Furber.

Charles G. Darrach, M. Am. Soc. C. E. (by letter).—On page 1024,* Mr. Bolton criticises the writer's comparisons between the hydraulic and the electric elevator, and illustrates by indicator diagrams the varying load imposed by an electric elevator. The pair of indicator diagrams in Fig. 7 are taken from the high-pressure cylinders of a Laidlaw-Dun-Gordon pump, with high-pressure steam cylinders, 17¾ ins. diameter, and two low-pressure cylinders of 20 ins. diameter, and 24-in. stroke. The building in which this pump is located has ten elevators, running through seventeen stories. A second pump, of the same design, with 16-in. and 18-in. cylinders, Mr. Darrach.



INDICATOR DIAGRAMS.

HIGH-PRESSURE CYLINDER, LAIDLAW-DUNN-GORDON PUMP.
ONE HIGH-PRESSURE CYLINDER 17¾ INS.
TWO LOW-PRESSURE CYLINDERS 20 INS.
STROKE 24 INS.
PUMP COMES TO A FULL STOP AT INTERVALS OF LESS THAN 1 MINUTE.

Fig. 7.

and 24-in. stroke, was running at the time the cards were taken, thus dividing and equalizing the load. The two pumps delivered into two pressure tanks 6 ft. in diameter and 22 ft. long.

Notwithstanding this installation, and with the advantage of the storage in the pressure tanks, each pump came to a dead stop at intervals of less than a minute, so that the cards do not show the disadvantage under which the pumps were operating; but it will be noticed that the variation in load was much greater in these pumps operating the hydraulic elevator than the variation in power on the engine driving the electric elevator, even when four cars were started together, and without the intervention of a storage battery.

The writer has stated, and shows by diagram made from actual tests (Fig. 8), that the economical range of efficiency of a steam engine is from a 40 to 50% underload to a 50% overload. The descrip-

* *Proceedings*, Am. Soc. C. E., for December, 1901.

Mr. Darrach. tion of the indicator diagrams, shown in Fig. 2, taken from an engine driving a dynamo direct to electric elevators, is as follows:

"Indicated	horse-power,	by largest card	....	154
"	"	" by smallest card	....	54
"	"	" average	....	108"

So that, if a properly rated engine of 108 H.-P. had been used in this instance, the range of economy would have been from 50% underload to 50% overload.

As the writer has noted, a compound, non-condensing engine, properly rated, will give an economy of from 23 to 24 lbs. of water per indicated horse-power; and the economy, within the range of operation recommended, will vary about 10% above that point. The break horse-power will run about 10% higher, or, say, 25 lbs. of steam per break horse-power-hour.

From tests made with a Laidlaw-Dun-Gordon pump, the economy per indicated horse-power runs from 24 to 26 lbs. of water, and the break horse-power will reach 30 lbs. or more; so that there is a decided advantage and economy in the steam unit operating the electric power over that operating the pumps.

With a Sprague electric-screw elevator, the writer has found that the starting current will vary from 50 to 100% above the regular hoisting current, and that the excessive starting current is largely governed by the car operator. This could be remedied by simply adding a starting contact button in the car.

Electric elevators recently installed in Philadelphia show a starting load not over 25% in excess of the running load, and it is simply a matter of modification of the mechanism to make the starting current much lower even than this. The writer would not advise the installation of an electric elevator plant as usually constructed without a storage battery, but the great cost of a storage battery may be discounted. In making an estimate for a plant which contemplated the use of a storage battery, it was found that, to get practically the same results, by simply changing the period over which the battery was to be used as storage (without operating the generators), the cost varied from $4 000 to $16 000.

Some three years ago, in obtaining proposals, the writer found that a hydraulic elevator plant (in which the pumps were operated by electric motors and no storage battery provided) cost as much as a Sprague screw elevator plant, including a storage battery which cost $18 000. The latter plant was adopted. The space occupied by the storage battery was less than would have been required for the pressure and return tanks for the hydraulic elevators, with the additional advantage that all the machinery could be closed down at night and on Sundays and holidays. This Sprague plant has been in operation

Mr. Darrach.

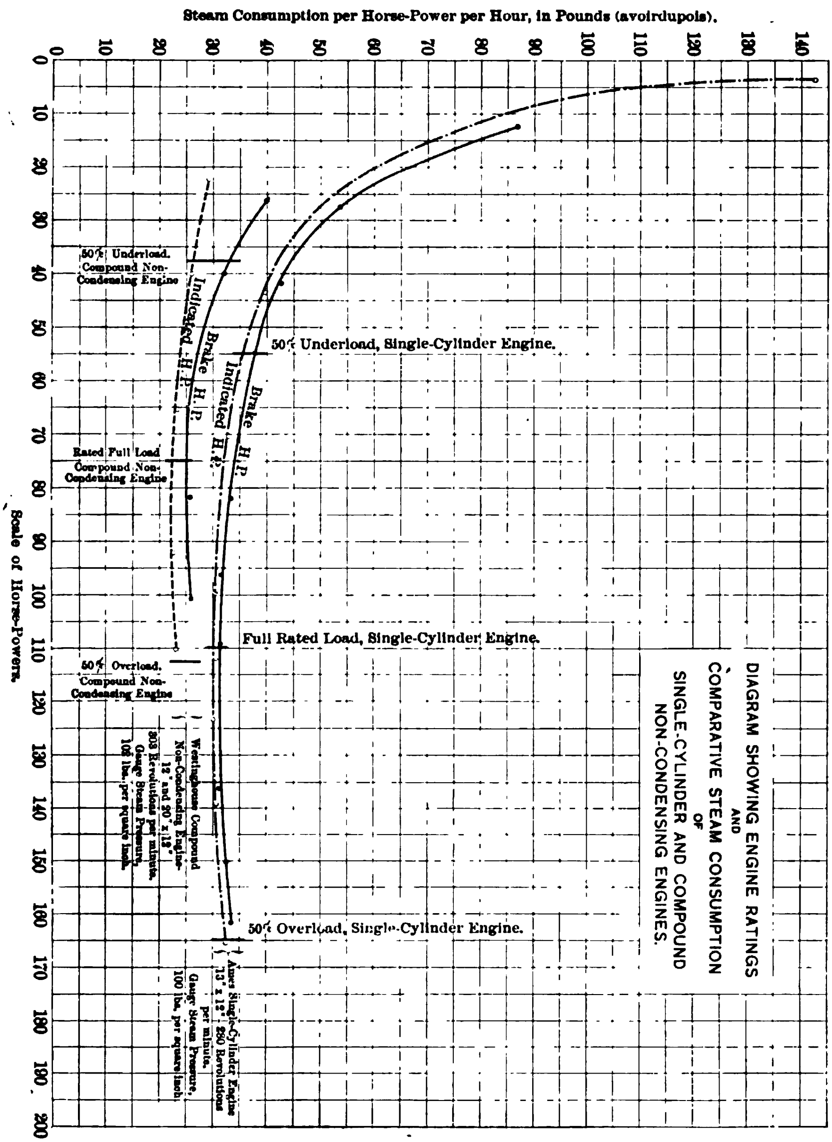


Fig. 8.

Mr. Darrach. for two and one-half years. There has been some trouble with the traveling nut, one of the screws being of rather softer metal than it should have been, but it will probably last another year. The other two screws, in all probability, will last at least two years more. The electrical connections and contacts have given no trouble. Beyond this, there is but little wear and tear, and it is the writer's opinion that, on the question of repairs, this will compare favorably with any high-duty hydraulic plant.

The electric-drum elevator has been relegated to apartment houses and small office buildings. The writer sees no difficulty in such a modification of this style of machine for all kinds of service.

As far as the matter of economy in operation is concerned, the writer can give no data as to the hydraulic machines, the information obtained from tests usually made cannot be taken as a fair indication of their every-day working economy, as the elevators under test conditions are generally run continuously at their utmost speed.

With the Sprague plant noted, the writer finds that the average economy, running through a period of thirty days, varied from 3½ to 4 kilowatt-hours per car-mile. If, for the sake of argument, this is increased by 25%, to allow for the losses in the generator, in the storage battery and in transmission, the result is 5 kilowatt-hours, or 6.7 horse-power-hours, per car-mile; say, 7.4 break horse-power-hours on the engine per car-mile, or, with a compound engine, 20 lbs. of coal per car-mile.

Another advantage in using an electric elevator and battery is that by its use only one, or at most two, generator power units need be provided, and, as indicated in the paper, all machinery and lights can be electrically operated. By this method there is a decided economy, especially in the smaller apparatus; for instance, a house pump having a capacity of only 60 galls. per minute showed an economy of 75% from wire to water in the tank, which means that this small pump could be driven with from 35 to 40 lbs. of steam per horse-power-hour; but, if driven directly by steam, it would probably have used over 100 lbs. of steam per horse-power-hour.

Another advantage to be gained is in the fact that the multiplicity of steam and exhaust and drip-pipes, with their numerous joints and valves to serve the various units, is avoided, first cost and expense in maintenance is reduced, and the comfort of the engine-room is enhanced.

On page 563, referring to elevators, the writer calls attention to certain necessities to provide against accident. He now calls attention to certain practices that should be avoided. The counterbalance should never be run in the elevator hatchway, and the elevator should be so designed that it would be impossible for the car to be raised without the direct application of power.

Philadelphia laws require that the hatchway doors shall be closed by the operation of the starting lever. This requirement is worse than

wrong; the hatchway doors should invariably be closed by a device independent of the starting mechanism. Mr. Darrach.

As an illustration of the viciousness of this device, the following instance may be given: A passenger was leaving the car, the pilot valve leaked, the car settled away from the platform, the doors suddenly closed, caught the passenger by the head, and held him prisoner. Had it not been for his presence of mind he would have been decapitated.

The premature closing of the elevator doors in this building became so notorious that the tenants made a practice of taking a running jump when leaving or entering the car.

These same laws have also required the installation of an air-cushion of a depth not less than one-sixth of the rise of the car, willy-nilly, thereby imposing untold hardships upon owners of buildings in which the aforesaid device had not previously been constructed. In one instance, where the rise was about 500 ft., the air-cushion was over 80 ft. high, and cost $25 000, whereas the cost of the elevator installation itself was only $10 000. In the writer's opinion, the air-cushion is a panacea for improper design, poor construction and negligent supervision.

In the days before the height of office buildings was more than 10 stories, the construction of an air-cushion was without serious objection or expense, but when it becomes so deep that it is forced above the first floor, or into the working travel of the car, the objections become serious, involving expensive construction, loss of speed, and unnecessary expenditure of power, heavy and small hatchway doors, discomfort to passengers from air currents, and danger should the car be caught in the air-cushion by the operation of the safety brakes.

If the air-cushion is extended below the working travel of the car, the hoisting apparatus must be designed to operate to the full depth of the air-cushion; and if this air-cushion is 30 to 40 ft. below the first floor, it is not only expensive in construction but becomes a receptacle for all sorts of filth and trash; in fact, it may be the cause of greater loss of life than it could possibly save. As the writer has stated, an air-cushion of sufficient depth to stop the car in case of a runaway is all that may be considered as a necessity.

The rupture of the suspending cables (the only legitimate reason for the need of an air-cushion) need never happen, and is a most remote contingency.*

* Recently there has been placed on the market what is known as the "Cruikshank Safety Device," and the writer understands that it has been accepted by the Philadelphia authorities in lieu of an air-cushion. This device consists of a number of metallic wires, running on either side of the elevator shaft from top to bottom. Between each floor "retarders" are strung in these vertical wires. The "retarders" are made of a pair of metallic plates, spaced the fraction of an inch apart, with staggered rivets around which the wires pass. The car is furnished with dogs which engage the "retarders" at a prearranged overspeed, and the car is slowed down by the friction of the retarder against the wires. If the car has not stopped by reason of the friction of the first retarder, it brings the second into action, and so on until the car is finally brought to a standstill.

[illegible] On page 8[illegible] attention is called to the advantages in the use of [illegible] lights, but, as generally used, they have some serious disadvantages. The glare from the highly illuminated filament produces a strain upon the eye which should be prevented, and some method should always be adopted to prevent this, either by the use of shades, ground lamps or frosted globes.

A bare incandescent lamp should no more be tolerated than a bare arc light. It will be found that if the filament is obscured no serious loss results, nor will there be any necessity for an increased number of lamps. Some eight years ago, in designing the lighting of the train-shed of the Reading Terminal Station, at Philadelphia, the writer used full frosted globes on all the arc lights, and had apparently a much better illumination than was obtained in the Pennsylvania Station, where plain glass globes were used. The reason is very simple. The glare of the bare arc or the bare filament is so great that Nature closes the iris; whereas, when the light is diffused, the iris opens and more light is admitted, without as great a strain upon the retina. Disregarding this fact, most electrical engineers prescribe, as an ultimatum, that the incandescent lamp must be placed bulb end down. For general illumination, the lamp should be placed bulb end up, screened with a frosted globe, and the light reflected from the ceiling.

Some years ago, the writer had occasion to light the chancel of a church. Incandescent lamps were placed in the rear, around the chancel arch, with reflectors converging all the rays of the various lamps upon a white Parian marble altar. The diffusion of light was so perfect that the priest, standing in front of the altar, did not cast an appreciable shadow.

The writer must take issue with the statement on pages 1012 and 1013 in which Mr. Bolton says:

> "The speaker regrets that he has some contradictions to apply to some of the figures presented in the paper, but, as regards New York practice, they certainly should not go forth as being definite.
>
> "To begin with, the author indicates the size of the boiler installation, basing it upon the cubical contents of the building, a most misleading element, as the cubical contents have no relation to the horse-power required."

The writer thinks that in this criticism Mr. Bolton is incorrect. The boiler-power required for the power plant, including lighting, elevator service, pumps, fans, etc., as well as heat required for change of air in ventilation, depends directly upon the cubical contents, and the only variation is the proportion of glass surface and the exposure.

For the amount of direct radiator surface required, the writer uses the formulas:

$$R = h \frac{t - t_1}{(T - t)a};$$

$$h = (k\,G + K\,W + 0.018\,N\,C)\,E;$$

Mr. Darrach.

in which R = square feet of prime radiator surface;

G = " " " exposed glass "

W = " " " " wall "

C = cubic feet of space to be heated;

N = number of times air is to be changed per hour;

k = B. T. U. transmitted per difference of 1° per hour per square foot of glass surface;

*K = B. T. U. " " " of 1° per hour per square foot of wall surface;

a = B. T. U. " " " of 1° per hour per square foot of radiator surface;

h = total heat units transmitted per difference of 1° per hour;

E = coefficient of exposure;

t = required temperature of room;

t_1 = temperature of outside atmosphere;

T = " " steam in radiator;

If $$P = \frac{Ra}{h} = \frac{t - t_1}{T - t},$$

then $$t = \frac{PT + t_1}{P + 1}$$

and the result is a formula by which the heating power of a system can be equated at a temperature of the outside atmosphere, other than that for which the system was designed. The observations should be made without the modification due to wind storms.

The writer has verified this formula by observations with the outside atmosphere from 7 to 30° Fahr.

The heating diagram (Fig. 9) was made from data taken at the office building of the United Gas Improvement Company, at the northwest corner of Broad and Arch Streets, Philadelphia.

This building has 12 stories and an attic, the ground plan has an area of 8 814 sq. ft., and, above the first story, an area of 7 386 sq. ft., with a width of 57 ft. Above the sidewalk, and within the exterior lines, the building contains 1 320 000 cu. ft.

There are, in all, 650 windows, and a large skylight, having in all 16 000 sq. ft. of glass, or about 25% of the exterior exposure. These windows are furnished with sash fasteners and "Golden" metallic weather strips.

The first story is heated with warm air, supplied by fans. The stair hall, elevator shaft, and the building above the first floor, are

* $K = \frac{5.286}{\Theta + 3.7}$, for good brick or stone walls; Θ = thickness of wall, in inches.

Mr. Darrach. heated by direct radiators under the windows. Exhaust ventilation is provided for the entire building, with fans in the basement for the first story and below, and in the attic for the rooms above the first story.

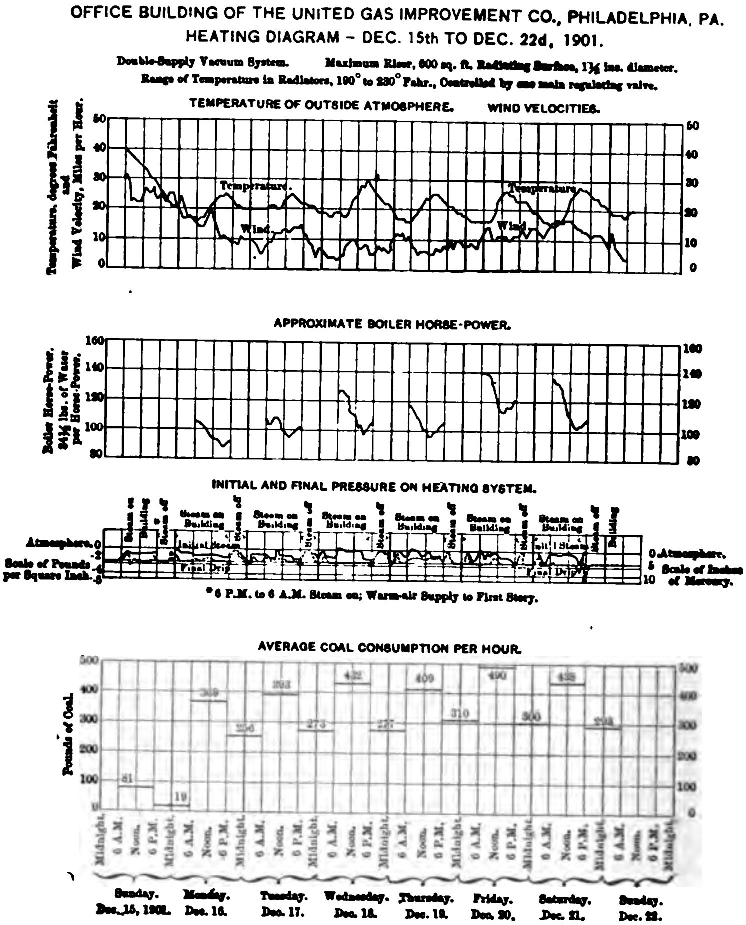


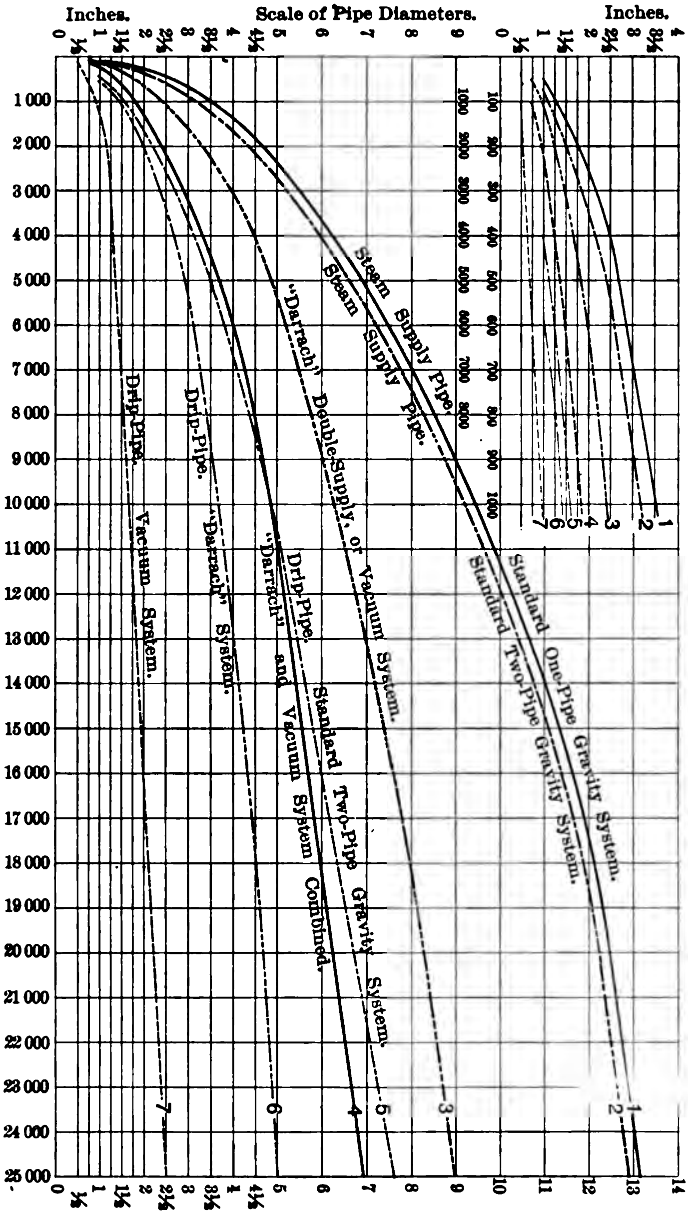
FIG. 9.

There are 2 800 sq. ft. of radiator coils for the indirect, and 12 700 sq. ft. of direct, radiation, making an equivalent of about 19 000 sq. ft. of direct radiation.

As power for elevators, lighting, fans, pumps, etc., is generated by gas engines, and the heating is entirely independent of the power, an

Mr. Darrach.

COMPARATIVE DIAGRAM OF STEAM HEATING AND DRIP-PIPES.



Scale of Radiating Surface, in square feet.

FIG. 10.

Mr. Darrach. excellent opportunity is presented for obtaining exact data as to the heating requirements.

Upon the diagram (Fig. 9) profiles made from hourly observations are shown:

1. The temperature of the outside atmosphere, in degrees, Fahrenheit.

2. The wind velocity, in miles per hour.

3. The approximate boiler horse-power (6 A. M. to 6 P. M.), calculated from the coal burned, rating 9 lbs. of water evaporated per pound of coal, and $34\frac{1}{2}$ lbs. of water per horse-power-hour.

4. The pressures (below the atmosphere) on the steam main in the boiler-room (initial), and on the drip-pipe (final).

5. The average number of pounds of coal burned per hour, in 12-hour periods.

From these data it will be found that 185 boiler horse-power would be required to heat the building at zero Fahrenheit, or, say, 7 000 cu. ft. per boiler horse-power.

The steam supply to the radiators is distributed on the double-supply system. The largest steam riser is $1\frac{1}{2}$ ins. in diameter, and serves 600 sq. ft. of radiation. A range of temperature of steam in the radiators from 190 to 230° has been obtained by the operation of one valve, regulating the temperature in the radiators to suit varying conditions of weather.

To illustrate the comparative dimensions of supply and drip-pipes, as used by the different systems, the diagram (Fig. 10) is submitted. Curve No. 3 shows the diameter of the risers for the corresponding radiator surface, if they are provided with a double supply, and the system is drained by gravity, or by the Webster Vacuum System, supplied either from top or bottom.

Curve No. 4 shows the diameters of the pipes in the Webster Vacuum System supplied from both ends.

The writer has found that the size of the drip-pipes noted in Curve No. 6 is sufficient for the risers on the gravity two-pipe system.

In tall buildings it is not considered good practice to make the least dimension of the riser less than 2 ins. diameter, increasing toward the source of supply; say, in a 24-story building, the riser serving 1 200 ft. of radiation, the largest diameter of the pipe on a one-pipe system would be not less than $3\frac{1}{2}$ ins., whereas, with a double-supply gravity system, it would be $2\frac{1}{2}$ ins., and with a double-supply vacuum system the diameter would be less than 2 ins.

In closing this discussion, the writer acknowleges the courtesy extended to him by the following gentlemen, and the opportunity given to obtain many of the data in the original paper and in the discussion: Mr. John Frigar, Chief Engineer, Drexel Building, Philadelphia; Mr. Samuel Dinsmore, Chief Engineer and Superintendent, Stephen Girard

Building, Philadelphia; Mr. Alonzo Dalton, Chief Engineer and Superintendent, Land Title and Trust Company's Building, Philadelphia; Mr. George Atkins, Chief Engineer and Superintendent, and Mr. W. G. Rice, Assistant Engineer, Real Estate Trust Company's Building, Philadelphia; Mr. William A. McEwen, Superintendent, and Mr. Wm. H. Hewitson, Chief Engineer, United Gas Improvement Company's Building, Philadelphia, and Mr. Benjamin Hough, Chief Engineer and Superintendent, North American Building. Mr. Darrach.

Vol. XXVIII. FEBRUARY, 1902. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE SUPPORTING POWER OF PILES.

Discussion.*

By E. Sherman Gould, M. Am. Soc. C. E.

Mr. Gould. E. Sherman Gould, M. Am. Soc. C. E. (by letter).—This paper is valuable in that it exhausts completely the mathematical side of the question of pile-driving, which comes up at intervals, with greater or less profit to the profession. No such thorough analysis as is given by the author can ever be deemed useless, because it either establishes a rational formula or demonstrates that none such can exist. It appears to the writer that this paper proves the latter proposition.

As a practical art, pile-driving depends wholly and exclusively upon practical experience. Mathematics has nothing whatever to do with it. At most, practice may utilize, under great reserve, some approved empirical formula, which is indeed only the embodiment and concise expression of practical experience. This is abundantly proved by the fact that the practice of pile-driving has been carried to a high degree of perfection, while the science is not yet established.

In the every-day practice of ordinary pile-driving on land and water, it is known that yellow pine piles, 10 to 15 ins. in diameter at the butt, driven to a practical refusal, or until they "fetch up," with a hammer weighing from 2 000 to 4 000 lbs., with a fall of from 5 to 20 ft., all according to circumstances, give satisfactory results; the only remaining question being how many shall be driven in the given area. In all

* This discussion (of the paper by Ernest P. Goodrich, Jun. Am. Soc. C. E., printed in *Proceedings* for December, 1901), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

Communications on this subject received prior to March 29th, 1902, will be published subsequently.

ordinary work, considerations of continuity of bearing result in spacing the piles so close together that their bearing capacity, as determined by any known formula, vastly exceeds the weight to be placed upon them. When any doubt exists as to the probable length of piles required, recourse is had to an actual test. If piles of great length are to be driven in uncertain ground, to support an important structure, the best available expert advice should be invoked, rather than the best mathematical talent. Mr. Gould.

The only obstacle to reducing any engineering proposition to a rational formula is uncertainty as to data. If all the data are known, to a certainty, the problem falls inevitably within the iron grasp of analysis, from which it cannot escape, and to which it must yield its secret. In pile-driving, data are conspicuously lacking. Of course the weight of the hammer, the height of fall, etc., are known, but all these factors are affected by unknowable and varying coefficients. What are the conditions under which a 4 000-lb. hammer, falling 20 ft., strikes the head of a pile, 15 ins. at the butt? In the first place, the force of the blow is entirely under the control of the man who has one hand on the throttle, and the other on the drum-brake. How lightly he can tap the pile. He can almost crack a hickory nut on it without injuring the kernel. But, admitting that he acts in good faith, and "lets go altogether," the falling weight must overhaul the rope and revolve the drum in its descent, and also overcome the friction of the leaders. Several men will be keeping the pile in position by jamming handspikes between it and the leaders, and by hauling it in by the headlines on the winch. There is also the brooming of the head of the pile, above the ring, upon which the hammer cushions itself to a greater or less extent. All these resistances are to be added to that offered to the pile by the substance through which it is being driven, and these circumstances—and many more—destroy all hope of a rational formula.

In the writer's opinion, no formula can be applied, and no intelligent guess made as to the bearing capacity of a pile, unless it is driven to a practical refusal of, say, 1 inch. The best way is to drive the pile down rapidly until it either refuses a high fall, or has gone down nearly to grade, and, in the latter case, to reduce the fall till refusal is exhibited, and then, if desired, apply the formula. He believes, also, that refusal can be estimated by eye without actual measurement; it is very noticeable when penetration becomes labored, and the pile is beginning to fetch up. All attempts at refinement of measurements of the fall and penetration have the fatal defect of retarding the rapidity with which the pile is sent home. When piles are driven down to a hard substratum there is, of course, no difficulty in telling when they are home, and all hammering should then be stopped.

Mr. Gould. Another element which makes for safety, but which baffles calculation, is the clinging action of the material through which the pile is driven, and which action is set up immediately after it has been allowed to come to rest. It is often impossible to draw a defective pile even a very short time after it has been driven, unless a few blows be given by the hammer to start it, when it may come up very easily. A pile which has gone down readily to-day may utterly refuse all further penetration under the same hammer and fall to-morrow; for this reason, driving should be continuous, till the pile is home.

The writer observes with some surprise that the author makes no mention of the paper* presented by Charles H. Haswell, M. Am. Soc. C. E., which gave rise to an instructive discussion. In this paper Mr. Haswell gave a formula, which, admitting a set of ½ in., and a factor of safety of 6, reduces to

$$L = 5\ W \sqrt{h} \qquad (1)$$

in which L = safe load, and W = weight of hammer, both in the same unit, and h = fall, in feet. Wellington's formula, given in the same paper, admitting a set of 1 in., reduces to

$$L = W h \qquad (2)$$

the nomenclature remaining the same. If a set of ½ in. be admitted, the same as in Equation (1), then Equation (2) reduces to

$$L = 1.33\ W h \qquad (3)$$

For falls of between 10 and 20 ft., Equations (1) and (3) give nearly equal values of L. Either is serviceable under average conditions.

In thus exalting the part which the trained judgment plays in the art of pile-driving, the writer does not wish to detract in the least from the high degree of analytical ability displayed by the author.

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* *Transactions*, Am. Soc. C. E., vol. xlii., p. 267.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXVIII. No. 3.

MARCH, 1902.

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS.

NEW YORK 1902.

American Society of Civil Engineers.

OFFICERS FOR 1902.

President, ROBERT MOORE.

Vice-Presidents.

Term expires January, 1903:	*Term expires January, 1904:*
HENRY S. HAINES,	CHARLES C. SCHNEIDER.
GEORGE H. BENZENBERG,	JOHN R. FREEMAN,

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Treasurer, JOSEPH M. KNAP.

Directors.

Term expires January, 1903:	*Term expires January, 1904:*	*Term expires January, 1905:*
JOHN F. O'ROURKE,	JOSIAH A. BRIGGS,	RICHARD S. BUCK,
HENRY B. SEAMAN,	GEORGE F. SWAIN,	GEORGE H. PEGRAM,
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HENRY B. RICHARDSON,	EDWARD C. CARTER,	EDMUND F. VAN HOESEN
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Assistant Secretary, T. J. McMINN.

Standing Committees.

THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

On Finance:	*On Publications:*	*On Library:*
JOSIAH A. BRIGGS,	JOHN F. O'ROURKE,	HENRY S. HAINES,
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WILLIAM J. WILGUS.	FRANK C. OSBORN.	CHARLES WARREN HUNT.

Special Committees.

ON ANALYSIS OF IRON AND STEEL:—Sub-Committee of the American Society of Civil Engineers (of the International Committee on Standards for the Analysis of Iron and Steel, of which Prof. J. W. Langley is Chairman)—Charles B. Dudley, William Metcalf. Thomas Rodd.

ON UNITS OF MEASUREMENT:—George M. Bond, William M. Black, R. E. McMath, Charles B. Dudley, Alexander C. Humphreys.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, George F. Swain, Alfred Noble, W. B. W. Howe, Louis C. Sabin, S. B. Newberry, Clifford Richardson, Richard L. Humphrey, F. H. Lewis.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK

TELEPHONE NUMBER, - - - 583 Columbus.
CABLE ADDRESS, - - "Ceas, New York."

Vol. XXVIII. MARCH, 1902. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

March 5th, 1902.—The meeting was called to order at 8.40 P. M., Joseph M. Knap, Treasurer, Am. Soc. C. E., in the chair; Charles Warren Hunt, Secretary; and present, also, 110 members and 11 visitors.

The minutes of the meetings of February 5th and 19th were approved as printed in the *Proceedings* for February, 1902.

Messrs. Julian Thornley and William Fitch Smith were appointed tellers to canvass the vote on the proposed amendment to the Constitution.

George S. Morison, Past-President, Am. Soc. C. E., presented his paper entitled "The Bohio Dam," illustrating it with lantern slides. The paper was supplemented by F. P. Stearns, M. Am. Soc. C. E., who described in detail the North Dike of the Wachusett Reservoir,

also using lantern slides. The paper was further discussed by Messrs. Allen Hazen, Edward P. North, Boyd Ehle, Theodore Paschke and the author. The Secretary presented a written discussion from William H. Burr, M. Am. Soc. C. E., and announced that he had received others from Messrs. A. G. Menocal, H. N. Pharr, Edwin Duryea, Jr., and C. A. Sundstrom. Owing to the lateness of the hour, these discussions were not read.

The tellers appointed to canvass the ballots on the proposed amendment to the Constitution, changing the method of election of members,* reported as follows:

Total number of ballots received		604
Without signature	2	
Not entitled to vote	1	
Defective (not filled out)	1	
	—	4
Total votes counted and found correct		600
In favor of the amendment (yes)	343	
Against the amendment (no)	257	
	—	600

The Chairman announced the proposed amendment lost, as the Constitution (Sec. 5, Art. IX) provides that an affirmative vote of two-thirds of all ballots cast shall be necessary to the adoption of any amendment.

Ballots for membership were canvassed and the following candidates were elected:

As Members.

Charles Anthony, Jr., Buenos Aires, Argentine Republic.
Wendell Phillips Brown, Cleveland, Ohio.
Emil Diebitsch, New York City.
Elstner Fisher, Hamilton, Ont., Canada.
William Gerig, Memphis, Tenn.
Robert Van Arsdale Norris, Wilkesbarre, Pa.
Commodore Perry Ruple, Cleveland, Ohio.

As Associate Members.

Charles William Bance, Jersey City, N. J.
William George Brenneke, St. Louis, Mo.
Clarence Austin Crane, New York City.
Charles Derleth, Jr., New York City.
James Hayward Harlow, Jr., Pittsburg, Pa.
Joseph Frederick Hasskarl, Philadelphia, Pa.
Walter Luman Lawton, Albany, N. Y.

* See *Proceedings*, Vol. xxviii, p. 35.

CHARLES GILLINGHAM MOORE, Cleveland, Ohio.
WILLIAM ELTON MOTT, Ithaca, N. Y.
HERSEY MUNROE, Washington, D. C.
JOHN MARBLE RACE, Santiago de Cuba, Cuba.
LEWIS DANIEL RIGHTS, East Berlin, Conn.
MARSHALL POPE ROBERTSON, New Orleans, La.
GEORGE ROMMEL, Jr., Lewes, Del.
WARREN BERTRAM TRAVELL, East Orange, N. J.

The Secretary announced the election of the following candidates by the Board of Direction on March 4th, 1902:

AS ASSOCIATE.

GIFFORD PINCHOT, Washington, D. C.

AS JUNIORS.

CLINTON TALCOTT BISSELL, Brooklyn, N. Y.
GEORGE WILLIAM LEE, Vilas, Pa.

Adjourned.

March 19th, 1902.—The meeting was called to order at 9.45 P. M., Alfred Noble in the chair; Charles Warren Hunt, Secretary; and present, also, 67 members and 10 guests.

A paper entitled "Thermo-Electric Measurement of Stress," by C. A. P. Turner, M. Am. Soc. C. E., was presented by the author.

The Secretary announced the death of CHARLES EDWARD HAMLIN, elected Associate January 2d, 1894; died January 20th, 1902.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

March 4th, 1902.—8.30 P. M.—Vice-President Schneider in the Chair; Charles Warren Hunt, Secretary; and present, also, Messrs. Buck, Croes, Knap, Kuichling, Pegram, O'Rourke, Seaman and Swain.

Action was taken in the matter of the appointment of a Special Committee on Rail Sections.

The following Local Committee of Arrangements for the Annual Convention, to be held at Washington, May 20th to 24th, 1902, was appointed:

GEORGE W. MELVILLE, *Chairman;*

JOHN BIDDLE,	C. B. HUNT,
WILLIAM M. BLACK,	D. E. MCCOMB,
D. S. CARLL,	ALEXANDER MACKENZIE,
BERNARD R. GREEN,	ALEXANDER M. MILLER,

H. M. WILSON.

The appointment, by the President, of the following Committee to report a Proposed Amendment to the Constitution, in regard to the method of election of members, and also in regard to the raising of the standard of qualification for admission to the Society, was announced:

H. G. PROUT, *Chairman;*	Representing	District	No. 1.
H. A. CARSON,	"	"	No. 2.
G. S. WILLIAMS,	"	"	No. 3.
THOMAS H. JOHNSON,	"	"	No. 4.
E. J. BLAKE.	"	"	No. 5.
DANIEL BONTECOU,	"	"	No. 6.
JAMES D. SCHUYLER,	"	"	No. 7.

One candidate for Associate and two for Junior were elected.*

Action was taken in regard to members in arrears for dues.

Applications were considered and other routine business transacted.

Adjourned.

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* See page 99.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, April 2d, 1902.—8.30 P. M.—At this meeting ballots for membership will be canvassed, and two papers will be presented; one by Marsden Manson, M. Am. Soc. C. E., entitled "A Brief History of Road Conditions and Legislation in California," and the other by Charles C. Wentworth, M. Am. Soc. C. E., on "Line and Surface for Railway Curves."

These papers were printed in the *Proceedings* for February, 1902.

Wednesday, April 16th, 1902.—8.30 P. M.—At this meeting two papers will be presented for discussion, as follows: "Is It Unprofessional for an Engineer to be a Patentee?" by Archibald R. Eldridge, M. Am. Soc. C. E.; and "The Stiffening System of Long-Span Suspension Bridges for Railway Trains," by Joseph Mayer, M. Am. Soc. C. E.

These papers were printed in the *Proceedings* for February, 1902.

Wednesday, May 7th, 1902.—8.30 P. M.—At this meeting ballots for membership will be canvassed, and a paper by George S. Webster and Samuel Tobias Wagner, Members, Am. Soc. C. E., entitled "The Pennsylvania Avenue Subway and Tunnel, Philadelphia, Pa.," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ADDITIONAL PAPER.

Attention is called to the paper entitled "Stresses in Columns Subject to Combined Axial and Transverse Loading," by Charles Worthington, M. Am. Soc. C. E., published in this number of *Proceedings*. This paper will not be presented for discussion at any meeting, but written communications on the subject are invited for publication, and its discussion may be called up by any member at any future meeting of the Society.

ANNUAL CONVENTION OF 1902.

The Thirty-fourth Annual Convention of the Society will be held at Washington, D. C., beginning on Tuesday, May 20th, 1902.

The general arrangements for the Convention are in the hands of a Committee of the Board of Direction, consisting of the following:

MORDECAI T. ENDICOTT,
GEORGE H. PEGRAM, CHAS. WARREN HUNT.

The following Local Committee of Arrangements has been appointed by the Board of Direction:

GEORGE W. MELVILLE, *Chairman;*

JOHN BIDDLE,	C. B. HUNT,
WILLIAM M. BLACK,	D. E. MCCOMB,
D. S. CARLL,	ALEXANDER MACKENZIE,
BERNARD R. GREEN,	ALEXANDER M. MILLER,

H. M. WILSON.

TOPICS FOR DISCUSSION AT THE ANNUAL CONVENTION.

No suggestions having been received in response to the request published in the February *Proceedings* under this head, it is here repeated in the hope that members will take some interest in this important matter.

It will be remembered that at the last three Conventions no formal papers have been presented, but that in their stead topics of general interest have been presented for discussion. The resulting attendance and interest in Convention meetings has shown the wisdom of the change, and the Committee on Publications will be glad to have members suggest topics suitable for discussion.

The following list, of the subjects which have already been discussed at Conventions, is here printed, in order to give some idea of the kind of subjects desired:

LIST OF SUBJECTS PRESENTED FOR DISCUSSION AT THE LAST THREE ANNUAL CONVENTIONS.

"Should the use of the method of Wheel Concentrations be discontinued in determining the Stresses in Railroad Bridges?

"In view of present knowledge of the Effect of Repeated Applications of Load, should Fatigue Formulas be used in Bridge Design?

"(*a*) Should Stream Contamination by the Sewage of Cities be absolutely prohibited by law?

"(*b*) Should the Purification of the Sewage of Cities be compulsory, and is this feasible for Large Cities?

"(*c*) Is Filtration the coming solution of the Pure-Water Question for Cities?

"What is the Proper Friction Coefficient for use in the design of Riveted Steel Pipe?

"What are the economic conditions under which Electricity may be profitably substituted for Steam in the operation of Branch Railroad Lines, and what are the engineering requirements to be considered in such substitution?

"What is the present development of the so-called Telferage System for moving either Freight or Passengers? What are the conditions under which that System is preferable to movement by Rail, and what is its adaptability to still further application in competition with Rail Lines?

" Height of Buildings.

(1) What considerations should limit the height of buildings?

(2) Do recent developments in construction, sanitation, intercommunication and economy of administration, warrant the removal of all restrictions?

" Recent Practice in Rails.

The progressive increase in weight; the increase in hardness, particularly in carbon; the sections in most general use; the effect of changes in weight, composition and section.

" Filtration of Water for Public Use.

The several processes now used for the removal of objectionable matter; their comparative sanitary effect, cost and reliability.

" Do the interests of the profession, and the duty of its members to the public, require that only those who are competent be allowed to practice as Civil Engineers? Under what authority, through what agency, and upon what evidence of competency, should applicants be admitted to the practice of Civil Engineering?

" Steel-Concrete Construction.

What stress in tension and compression should be allowed in concrete?

What is the proper modulus of elasticity of concrete?

In Steel-Concrete Arches:

(1) What should be the ratio of steel section to concrete section, and what is the best form and disposition of the former?

(2) What consideration should be given to temperature changes and consequent stresses?

(3) What are the best proportions for concrete, and what is the best method of placing it?

" The Decolorization of Water.

When is it necessary? How may it be accomplished?

" The Consumption of Water in Municipal Supplies and the Restriction of Waste."

ACCESSIONS TO THE LIBRARY.

DONATIONS.*

(From February 12th to March 12th, 1902.)

AN ELEMENTARY BOOK ON ELECTRICITY AND MAGNETISM AND THEIR APPLICATIONS.

A Text-Book for Manual Training Schools and High Schools, and a Manual for Artisans, Apprentices, and Home Readers. By Dugald C. Jackson, M. Am. Inst. E. E., and John Price Jackson, M. Am. Inst. E. E. ½ Leather, 8 × 5¼ ins., 11 + 482 pp., illus. New York, The Macmillan Company, 1902. $1.40. (Donated by Dugald C. Jackson.)

While this book is more especially intended for an elementary text-book, the authors believe that it will prove a useful manual for apprentices and artisans, and have exerted every effort to make it clear, forceful and of strict scientific accuracy. There is an index of fourteen pages.

RECHERCHES SUR LES RIVIÈRES A MARÉE.

By H.-L. Partiot. Paper, 11 × 7 ins., illus., with atlas, 12 × 9 ins. Paris, E. Bernard & Cie., 1901. (Donated by the Author.)

The Contents are: Formulas nécessaires à l'étude des rivières à marée; Détermination du régime futur d'un cours d'eau maritime; Étude de l'embouchure des rivières; La Seine maritime; La Loire maritime; Feuilles de hauteurs d'eau et tableaux du cubage.

CAST IRON.

A Record of Original Research. By William J. Keep, M. Am. Soc. M. E., M. Am. Inst. Min. E. Cloth, 9 x 6 ins., 15 + 225 pp., illus. New York, John Wiley & Sons, 1902. $2.50.

The author states that since May, 1885, he has endeavored, by his method of testing, to discover the influence of the chemical elements in cast iron, and the results were recorded in the *Transactions* of the American Institute of Mining Engineers, prior to 1894. As a member of the Testing Committee of the American Society of Mechanical Engineers, he also made extensive experiments to determine the physical properties of cast iron, the results of which are recorded in the *Transactions* of that society. This volume contains the results of this whole line of research. The headings of chapters are: Definitions; Graphic Records; Methods of Investigation; Crystallization of Cast Iron; Carbon in Cast Iron; Silicon in Cast Iron; Shrinkage of Cast Iron; Keep's Cooling Curves, a Study of Molecular Changes in Metals Due to Varying Temperatures; Phosphorus in Cast Iron; Sulphur in Cast Iron; Manganese in Cast Iron; Segregation; Strength of Cast Iron; Impact; Graphic Method for Closely Approximating the Percentage of Silicon, the Shrinkage, and Strength of Any Other Size of Casting than the One Tested; Hardness or Workability of Metals; Mechanical Analysis or Chemical Analysis for Regulating Foundry Iron; Chemical Analysis Will Not Account for all Physical Properties of Cast Iron; Test-Bars; Keep's Testing Apparatus; Pig Irons and Silicon Irons; Testing Small Samples of Pig Iron; Aluminum in Cast Iron; Influence of Various Metals in Cast Iron. There is an index of sixteen pages.

The following gifts have also been received:

Am. Iron and Steel Assoc. 86 nos.
Am. Soc. for Prevention of Cruelty to Animals. 1 pam.
Boston Testing Laboratories. 4 vol.
Coll. degli Ingegneri e Architetti in Palermo. 1 pam.
Davidson, George. 3 pam.
Fitchburg City Engr. 1 pam.
Heyland, Alexander. 4 pam.
Jackson, William. 5 bound vol., 3 pam.
Königliche Technische Hochschule. 1 pam.
Madras Pub. Works Dept. 1 bound vol.
Mass. Board of Harbor and Land Commrs. 1 bound vol.
Mass. Bureau of Statistics of Labor. 9 bound vol.
Morison, George S. 1 pam.
Munn & Co. 21 nos.
N. Y. Board of R. R. Commrs. 2 bound vol.
North of England Inst. of Min. and Mech. Engrs. 1 pam.
Platt, T. C. 1 pam.

* Unless otherwise specified, books in this list have been donated to the Library by the Publisher.

Read, R. L. 7 pam.
Richardson, Clifford. 1 pam.
Schreiber, Collingwood. 1 vol.
Swain, G. F. 1 pam.
Switzerland hydrometrische Abteilung des eidg. Oberbauinspektorates. 7 pam.
Thompson, Robt. A. 1 pam.
Thrupp, Edgar C. 1 pam.
U. S. Bureau of Statistics. 1 bound vol.
U. S. Chief of Engrs. 14 pam.
U. S. Commr. of Education. 1 bound vol.
U. S. Geological Surv. 1 bound vol., 2 vol., 7 pam.
U. S. Interstate Commerce Comm. 5 pam.
U. S. Navy Dept. 1 vol., 26 pam.
U. S. Pub. Roads Inquiries. 1 pam.
U. S. Weather Bureau. 2 pam.
Univ. of Texas Mineral Surv. 1 pam.
Wallace, J. F. 1 vol.
Wallheim, Albert. 1 pam.
Whipple, George C. 1 pam.

BY PURCHASE.

Bibliothèque du Conducteur de Travaux Publics; Publiée sous les Auspices de Messieurs les Ministres des Travaux Publics, de l'Agriculture, de l'Instruction Publique, du Commerce et de l'Industrie, de l'Intérieur, des Colonies, de la Justice. 43 vols. Paris, P. Vicq-Dunod et Cie., 1894–1902.

Le Chemin de Fer Métropolitain de Paris; Description du Réseau Projeté—Lignes Actuellement Exécutées, Usine de Bercy—Exploitation des Lignes en Service, Lignes Actuellement en Construction. Par A. Dumas. Paris, Ch. Béranger, 1901.

Deutsche Bauzeitung (to complete set). 13 vols.

Summary of Accessions.

February 12th to March 12th, 1902.

Donations (including 7 duplicates and 57 numbers completing volumes of periodicals)	184
By purchase	57
Total	241

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
BARBER, WILLIAM DAVIS, Asst. Engr. in Chg., Div. of Pumping Station Constr. and Repairs, Dept. of Public Works (Res. 1700 Buckingham Pl., Chicago, Ill.)..	Assoc. M. M.	Sept. 1, 1897 Jan. 8, 1902
DIEBITSCH, EMIL, Engr. and Supt. for John Peirce, 277 Broadway (Res., 80 Washington Sq.), New York City..................................	Jun. Assoc. M. M.	Feb. 28, 1893 Oct. 6, 1897 March 5, 1902
FISHER, ELSTNER, Gen. Supt. and Chf. Engr., T., H. & B. Ry. Co., Hamilton, Ont., Canada..............	Jun. Assoc. M. M.	Apr. 3, 1889 June 2, 1897 March 5, 1902
NORRIS, ROBERT VAN ARSDALE, Chf. Engr., Pennsylvania R. R. Coal & Water Cos., Wilkesbarre, Pa.....................	Jun. M.	Dec. 7, 1887 March 5, 1902

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BRENNEKE, WILLIAM GEORGE, (Brenneke & Fay, Cons. Civ. Engrs.), 1000 Fullerton Bldg., St. Louis, Mo..................................		March 5, 1902
CRANE, CLARENCE AUSTIN, Asst. Engr., Aqueduct Comm., Jerome Park Reservoir, 121 West 70th St., New York City......................		March 5, 1902
HASSKARL, JOSEPH FREDERICK, U. S. Engr. Office, 2310 Hancock St., Philadelphia, Pa..		March 5, 1902
LAWTON, WALTER LUMAN, Structural Engr. for N. Y. State Archt., 132 Chestnut St., Albany, N. Y..		March 5, 1902
MCCAFFERY, RICHARD STANISLAUS, Supt., Santa Fe Gold & Copper Mining Co., San Pedro, N. Mex.......................	Jun. Assoc. M.	May 4, 1897 Sept. 4, 1901
MOTT, WILLIAM ELTON, Asst. Prof. of Civ. Eng., Cornell Univ., Ithaca, N. Y....		March 5, 1902
MUNROE, HERSEY, Topographer, U. S. Geological Survey, Washington, D. C........................		March 5, 1902
SHORT, WILLIAM AMBROSE DUDLEY, Signal Engr., Cincinnati Div., C., N. O. & T. P. Ry. (Res., 90 Market St.), Lexington, Ky..................		Feb. 5, 1902
SMITH, ALBERT HENRY, Mech. Engr. and Chf. Insp., Toledo Branch of American Bridge Co., 1309 Utah St., Toledo, Ohio..............		Oct. 2, 1901

ASSOCIATES.

Date of Membership

FULLER, ALMON HOMER,
Prof. of Civ. Eng., Univ. of Washington, University Station, Seattle, Wash.................. Jun. Apr. 4, 1899; Assoc. Feb. 4, 1902

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Forester, U. S. Dept. of Agriculture, and Chief of Bureau of Forestry (Res., 1615 Rhode Island Ave.), Washington, D. C.. March 4, 1902

JUNIORS.

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258 Ryerson St., Brooklyn, N. Y........................ March 4, 1902

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391 W. Jackson Blvd., Chicago, Ill...................... Feb. 4, 1902

RAYNOR, CLARENCE WEBSTER,
Jun. Engr., U. S. Engr. Office, 33 Campau Bldg., Detroit, Mich.. Feb. 4, 1902

CHANGES OF ADDRESS.

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WEBSTER, CHARLES EDWARD..........Prin. Asst. Engr., Western Dist., N. Y. C. & H. R. R. R., Syracuse, N. Y.

ASSOCIATE MEMBERS.

AYRES, CLARENCE MORTON...........Tuscaloosa, Ala.

BEUGLER, EDWIN JAMES.............Res. Engr., The Boston Terminal Co., Boston, Mass.

HAZARD, ERSKINE ....Chf. Surv., Lancaster Gold Mining Co., and The Lancaster West Gold Mining Co., Box 3197, Johannesburg, South Africa.

HOMAN, WILLIAM MACLEAN ....Cons. Engr., 1 Mutual Bldgs., Smith St., Durban, Natal, South Africa.

KAHN, JULIUS......................1117 Union Trust Bldg., Detroit, Mich.

LUND, GEORGE ALFRED..............1131 Central Ave., Bridgeport, Conn.

MARTIN, JAMES WILLIAM ....525 Van Buren St., Pueblo, Colo.

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VOGLESON, JOHN ALBERT.............2d Asst. Engr., Impvt., Extension and Filtration of Water Supply, Torresdale Filters, State Road and Pennypack St., Station "M," Philadelphia Pa.

Whiskeman, James Peter...........Bureau of Bldgs., Borough of Manhattan, 220 Fourth Ave., New York City.
Whistler, John T....................1823 Kalorama Ave., Washington, D. C.
Zarbell, Elmer......................Care, Chf. Engr., L. & N. R. R., Louisville, Ky.

JUNIORS.

Dixon, De Forest Halsted..........166 Remsen St., Brooklyn, N. Y.
Macy, Elbert Clyde................Asst. Engr., C. G. W. Ry., St. Paul, Minn.
Spencer, Louis Bernard............Box 448, Salt Lake City, Utah.
Wells, Clinton Glencairn........ Prin. Asst. Engr., Maryland & Pennsylvania R. R., North Ave. and Oak St., Baltimore, Md.

FELLOWS.

Darwin, Harry Gilbert............Chf. San. Insp., Tenement House Dept., 44 Court St. (Res., 703 Vanderbilt Ave.), Brooklyn, N. Y.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(February 12th to March 12th, 1902.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Eng., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Can.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Institute, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 30c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 35c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England.
(22) *Iron and Coal Trades Review*, London, England.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, 75c.
(29) *Journal*, Society of Arts, London England.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des Ecôle Spéciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*. Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Eng., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 75c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 10c.
(47) *Mechanical Engineer*, Manchester, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Institute of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 10c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.

Bridge.

Swing Bridges.* (21) Serial beginning May, 1901.
The Triangulation for Bridge No. 4 across the East River, New York City. Oscar Erlandsen. M. Am. Soc. C E. (13) Feb. 13.
The Testing of Railway Bridges. (12) Feb. 14.
The Fern Hollow Highway Arch Bridge.* (14) Serial beginning Feb. 15, ending Feb. 22.
Plate-Girder Webs.* T. Graham Gribble, Assoc. M. Inst. C. E. (11) Feb. 21.
A Non-Continuous Swing Bridge.* (13) Feb. 27.
The Luxemburg 277-ft. Stone Arch Viaduct.* (13) Feb. 27.
The Cambridge Bridge.* (Extracts from article in *Technology Review.*) (15) Feb. 28.
Roath Bridge, Great Western Railway.* (12) Feb. 28.
Westvale Concrete Bridge.* J. R. Worcester. (60) Mar.
The Erection of the Luxemburg Stone Arch.* (14) Mar. 1.
The Zanesville Concrete-Steel Y Bridge.* (14) Mar. 1.
Étude Théorique sur la Résistance des Voutes. Léon Cosyn. (35) Serial beginning Sept., 1901.
Le viaduc de Müngsten (Allemagne).* René Philippe. (35) Serial beginning Jan., ending Feb.
Influence des efforts dus à l'inclinaison et à l'action des freins sur les poutres principales d'un pont de chemin de fer à Forte Rampe.* M. Rey. (38) Feb.
Note sur les conditions d'établissement et de stabilité des ponts, ponceaux et aqueducs en maçonnerie, murs de soutènement.* L. Lanave. (36) Serial beginning Feb. 10.
Ponts levants du canal de l'Elbe à la Trave.* (33) Feb. 15.

Electrical.

Electric Power Plants in the Mining Districts of Northern California.* G. P. Grimsley. (16) Serial beginning Aug. 31, 1901.
High-Speed Electric Railway Car of the Allgemeine Elektricitats Gesellschaft, Berlin.* O. Lasche. (27) Serial beginning Sept. 14, 1901.
The Induction Motor for Electric Railways. (27) Serial beginning Sept. 14, 1901.
The Debt of Electrical Engineering to C. E. L. Brown.* B. A. Behrend. (27) Serial beginning Nov. 16, ending Mar. 1.
The Destructive and Lethal Effects of High-Pressure Currents. Dr. Margaret A. Cleaves. (26) Serial beginning Nov. 29, ending Feb. 28.
The Economic Design and Management of Telephone Exchanges. Arthur V. Abbott. (27) Serial beginning Dec. 7, 1901.
The Testing and Management of Electric Motors.* P. T. White. (26) Serial beginning Dec. 27, 1901.
Engines and Batteries for Power Stations. (26) Serial beginning Jan. 24.
Methods of Illumination. Louis Bell. (42) Feb.
South London Electricity Works.* (26) Feb. 7.
Earth Currents Derived from Distributing Systems.* E. Basil Wedmore. (Abstract of paper read before Inst. of Elec. Engrs.) (26) Serial beginning Feb. 7, ending Feb. 14.
Recent Development of the Atomic Theory and its Connection with Light and Electricity. C. C. Garrard. (26) Serial beginning Feb. 7, ending Feb. 14.
Modern Commutating Dynamo Machinery, with Special Reference to the Commutating Limits.* H. M. Hobart, M. I. E. E. (Paper read before International Eng. Congress.) (11) Serial beginning Feb. 7, ending Feb. 21.
The Brush Electrical Engineering Company.* (11) Serial beginning Feb. 7, ending Feb. 14.
Practical Notes on Continuous-Current Distributing Mains.* John C. A. Ward. (Abstract of paper read before Glasgow Section of Inst. of Elec. Engrs.) (47) Feb. 8.
Electricity in Glass Manufacture.* (12) Feb. 14.
Bermondsey Electricity Works.* (26) Feb. 14.
The Westinghouse Integrating Wattmeter. (26) Feb. 14.
Wireless Telegraphy. H. W. Sullivan. (26) Feb. 14.
Some Results of a Secondary Battery in a Traction Station. (26) Feb. 14.
The Leakage of Current from Buried Bare Conductors.* (26) Feb. 14.
How to Construct an Efficient Wireless Telegraph Apparatus at a Small Cost.* A. Frederick Collins. (19) Feb. 15.
Rotary Disks. Alfred G. Dell. (27) Feb. 15.
Energy Consumption and Electric Automobile Performance.* H. W. Alden. (27) Feb. 15.
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Storage Batteries in the Baltimore Belt Line Tunnel Power Plant.* (27) Feb. 15.
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Designing of Continuous Current Dynamos. Aubrey Clayton. (26) Feb. 21.
An Improved Theater Dimmer.* (27) Feb. 22.
The Dalles, Oregon, Transmission Plant.* (27) Feb. 22.
Armature Interference and Brush Position. H. M. Hobart. (26) Serial beginning Feb. 28.
The New Direct Current Works of the City of London Electric Lighting Company.* (26) Feb. 28.
Telpherage; a System of Electric Traction.* A. S. Clift. (10) Mar.

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Electrical—(Continued).

Electric Power in American Cotton Mills.* W. B. Smith Whaley. (10) Mar.
Electric Appliances in Ship-building Yards.* Sydney F. Walker. (9) Mar.
The Generators, Transformers and Rotary Converters for the Manhattan Railway.* (64) Mar.
Slaby-Arco Wireless Telegraph Apparatus.* A. Frederick Collins. (27) Mar. 1.
The National Telephone Company's New Exchange at Kensington, London.* (27) Mar. 1.
Two Recent English Central Stations.* (27) Mar. 1.
The New Toll Line Boards of the Chicago Telephone Company.* (27) Mar. 1.
Power Transmission Plant for Lighting the Cornwall Canal, Canada.* (27) Mar. 1.
The General Problem of Wave Propagation over Non-Uniform Conductors. M. I. Pupin. (27) Mar. 1.
The Thomson Method of Making Tubes Electrically.* (20) Mar. 6.
The Guarini Repeating Wireless Telegraph System.* A. Frederick Collins. (46) Mar. 8.
Development of a Great Water Power System at Hartford, Conn.* Alton D. Adams. (27) Mar. 8.
District Electrical Supply.* (27) Mar. 8.
The Heany Enclosed Arc Lamp.* E. Trier. (27) Mar. 8.
La Construction et l'Établissement des Alternateurs.* (36) Serial beginning Oct. 10, 1901.
Transmission de force par l'électricité dans les ateliers de la Palmer Shipbuilding and Iron Co. à Jarrow-sur-Tyne (Angleterre).* Ch. Dantin. (33) Feb. 1.

Marine.

Graphic Analyses of Propeller Reactions. J. Millen Adam. (11) Serial beginning Sept. 20, 1901.
The New Bermuda Floating Dock. (11) Feb. 14.
Naval Engineers. D. B. Morison. (Paper read before North-East Coast Inst. of Engrs. and Shipbuilders.) (11) Serial beginning Feb. 14, ending Feb. 21.
The Armoured Cruiser *Good Hope*.* (11) Feb. 28.
The Russian Battleship *Pobieda*.* (12) Feb. 28.
Water-Tube Boilers.* (Report of Committee appointed by the Admiralty to inquire into the question of water-tube boilers for the Navy.) (11) Serial beginning Feb. 28.
La Navigation Sous-Marine.* H. Noalhat. (36) Serial beginning Feb. 25, 1901.
Deformation and résistance des coques de navire, flexion transversale. H. Chaigneau. (36) Serial beginning Feb. 25, 1902.

Mechanical.

Improvements in the Steam Engine.* W. H. Wakeman. (41) Serial beginning Jan., 1901.
Die Forging.* Joseph Horner. (11) Serial beginning May 3, 1901, ending Feb. 14, 1902.
The Hydraulic Brake.* Robert A. Bruce. (47) Serial beginning May 11, 1901.
Bevel-Gear Cutting Machines at Paris.* Fred. J. Miller. (47) Serial beginning June 8, 1901.
Machinery at the Pan-American Exposition.* (20) Serial beginning July 18, 1901.
Design and Construction of Machine Tools.* Thomas R. Shaw. (47) Serial beginning July 28, 1901.
Pneumatic Tools at the Glasgow Exhibition.* (11) Serial beginning Aug. 23, 1901.
The Principles and Design of Modern Drying Plant.* (12) Serial beginning Oct. 4, 1901.
Some Typical Experimental Steam Engine Installations.* W. W. F. Pullen, Assoc. M. Inst. C. E., M. I. Mech. E. (47) Serial beginning Oct. 26, 1901.
Air Motors.* W. C. Popplewell, Assoc. M. Inst. C. E. (47) Serial beginning Nov. 9, 1901.
Machine Tools at the Glasgow Exhibition.* Fred. Bathurst. (26) Serial beginning Nov. 22, 1901.
Hydraulic Pumping Machinery.* Fr. Froelich. (11) Serial beginning Dec. 6, 1901.
Shaft Fractures Due to Oscillations in Direct-Coupled Units at Critical Speeds. Julius Frith and Ernest H. Lamb. (47) Serial beginning Dec. 28, 1901.
Shrinkage and Pressure-Joints.* William Ledyard Cathcart. (6) Jan.
The Paris Motor Car Show.* (12) Serial beginning Jan. 3.
Some Notes on Steam Turbines.* F. J. Warburton. (Paper read before North-East Coast Inst. of Engrs. and Shipbuilders.) (12) Feb. 7.
The Bignall & Keeler Duplex Pipe Machine.* (20) Feb. 13.
Gas and Gasoline Engine Ignition. Albert Stritmatter. (62) Serial beginning Feb. 13, ending Feb. 20.
Plate Springs.* (12) Feb. 14.
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Steam Boilers for Electric Power Stations. C. E. Stromeyer, M. I. C. E. (Paper read before Manchester Section of Inst. of E. E.) (47) Feb. 15.
Mechanical Plant of the Albany Station of the New York Central & Hudson River Railroad Company.* (14) Feb. 15.
Crude Petroleum as Fuel. Robert P. Skinner. (19) Feb. 15.
New Carburetted Water Gas Plant at Oldham, England.* (Reprint from *Journal of Gas Lighting*.) (24) Feb. 17.
A Rotary Brush System of Feeding Pulverized Fuel to Furnaces.* (13) Feb. 20.

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The Crystal Palace Motor Car Show.* (12) Feb. 21.
The Dürr Water-Tube Boiler.* S. J. Thompson. (22) Feb. 21.
The Working Loads for Manila Rope.* C. W. Hunt. (11) Feb. 21.
Appliances Driven by Compressed Air.* W. C. Popplewell, Assoc. M. Inst. C. E. (47) Feb. 22.
Central Heating & Lighting Plant for the County Buildings, Indianapolis, Ind.* (14) Feb. 22.
The Efficiencies of Chain Blocks.* (47) Feb. 22.
Gas and Other Internal Combustion Engines.* Dugald Clerk. (Paper read before Institution of Engrs. and Shipbuilders in Scotland.) (47) Serial beginning Feb. 22.
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The Nutting Automatic Multiple Spindle Drill.* (20) Feb. 27.
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The Station of the Independent Electric Light and Power Co., San Francisco, Cal.* (64) Mar.
Evolution of the Shaft Governor.* R. C. Carpenter. (Paper read before the Engine Builders' Assoc.) (64) Mar.
Experiments on Spiral Springs. Chas. H. Benjamin and Roy A. French. (Paper read before Am. Soc. M. E.) (25) Mar.
A New Tender Draft Casting for Friction Draft Gear.* Frank B. Kleinhans. (25) Mar.
The Briquetting of Fuels and Fine Mineral Ores.* Wm. Gilbert Irwin. (9) Mar.
Efficiency of Bituminous Coal. Harlan J. German. (39) Mar.
Correcting for Variations in Indicator Springs.* A. Koob. (64) Mar.
Hampton Boiler Plant; Description of a New Boiler Plant of the D., L. & W. Coal Mining Department at Scranton, Pa.* (45) Mar.
Horse-power of Belting and Pulleys.* E. C. De Wolfe. (64) Mar.
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A New Valve Gear for Gas, Steam and Air Engines.* Ernest W. Naylor. (Paper read before Am. Soc. M. E.) (41) Mar.
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Ore Handling at Furnaces. Waldon Fawcett. (46) Mar. 8.
The Table Photometer and the Standard Pentane Lamp. (Abstract from the *Journal of Gas Lighting.*) (24) Mar. 10.
Étude des Machines à Vapeur par le Diagramme Entropique. J. Boulvin. (37) Serial beginning Mar., 1901.
Condenseurs par Mélange et Pompes à Air.* Joseph Nadal. (37) Serial beginning June, 1901.
Les Moteurs à Gaz des Hauts Fourneaux. Jules Deschamps. (37) Serial beginning July, 1901.
Essai sur la Théorie des Moteurs à Gaz. Jules Deschamps. (37) Serial beginning July, 1901.
Appareils de Sureté des Chaudières à Vapeur. François Sinigaglia. (37) Serial beginning July, 1901.
Nouvelles Voitures à Air Comprimé de la Compagnie Générale des Omnibus à Paris.* G. Boëto. (33) Serial beginning July 13, 1901.
Expériences sur une Machine à Vapeur de MM. Weyher et Richemond. J. Hirsch. (37) Serial beginning Aug., 1901.
Application du principe de la conservation de l'énergie au fonctionnement des ventilateurs centrifuges.* A. H. Courtois. (37) Jan.
Les surchauffeurs de vapeur; progrès récents réalisés dans leur construction.* Maurice Miet. (33) Feb. 1.
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Ventilateurs pour hautes pressions mus par turbines à vapeur.* A. Rateau. (33) Feb. 8.
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Pompes centrifuges à haute pression avec moteurs électriques et turbines à vapeur. A. Rateau. (33) Feb. 15.
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La vapeur surchauffée, de 1827 à nos jours.* G. Loffet. (36) Serial beginning Feb. 25.

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Metallurgical.

Iron Foundries and Foundry Practice in the United States.* (12) Serial beginning Sept. 27, 1901.
Modern Methods of Gold Extraction.* Walter E. Koch. (58) Jan.
The David Copper Process.* (19) Feb. 22.
Some Unsolved Questions of Ore Treatment; A Consideration of Some of the Mechanical and Other Imperfections in Milling Processes.* O. H. Howarth. (45) Mar.
Anaconda Copper Mining Company's New Reduction Works.* (16) Mar. 1.
L'Épuration des Gaz de Haut Fourneau.* Jules Deschamps. (37) Serial beginning June, 1901.
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Chargeuse électrique, système Wellman, pour fours Siemens-Martin.* (33) Feb. 15.

Military.

The Evolution of Fire-Arms and Ordnance and Their Relation to Advancing Civilization. Joseph Wheeler. (3) Mar.
Le Matériel d'Artillerie.* (37) Serial beginning Feb., 1901.

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Notes on Mine Hoisting Engines. Robert Peele. (6) Jan.
Dredging for Fine Gold in Idaho.* Robert Bell. (16) Feb. 15.
The Coos Bay Coal Fields.* Cleveland Rockwell. (16) Serial beginning Feb. 15.
Iowa's Iron Mine.* S. W. Beyer. (16) Feb. 22.
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Underground Compressed-Air Mine Plant; the Application of Compressed Air to Rock Drills, Pumps, Hoisting Engines, and Coal Cutters. Robert Peele. (45) Mar.
Conveying Machinery in Coal Mining.* S. Howard-Smith, M. Am. Soc. M. E. (10) Mar.
Electricity in Mining.* George H. Gibson. (16) Mar. 1.
Coal Cutting by Machinery in British Collieries.* Sydney F. Walker. (16) Mar. 8.
Les nouveaux fonçages par congélation.* H. Schmerber. (33) Serial beginning Jan. 18, ending Feb. 1.

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Railroad.

Locomotive Draft Appliances. (25) Serial beginning Oct., 1901.
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The Balancing of Locomotives. W. E. Dalby. (11) Serial beginning Nov. 22, 1901; (47) Serial beginning Nov. 28, 1901.
Electric Traction on Railways. (21) Serial beginning Jan., ending Feb.
Compound Tank Locomotive, Indian-Netherlands Railway, Java.* (12) Serial beginning Jan. 3.
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The Relation of Energy and Motor Capacity to Schedule Speed in the Moving of Trains by Electricity.* Cary T. Hutchinson. (42) Feb.
American Engineer Tests of Locomotive Draft Appliances; Tests of Locomotive Stacks.* W. F. M. Goss. (25) Serial beginning Feb.
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A Portable Accelerometer for Railroad Testing. F. B. Corey. (Extract from paper presented before Am. Soc. M. E.) (15) Feb. 14.
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Notes on the Wear of Journals.* David Van Alstine. (Reprinted from *Proc.*, North-West Ry. Club.) (15) Feb. 21.

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The Design and Construction of Railway Carriages in India.* C. F. Bamford, Assoc. M. Inst. C. E.) (11) Serial beginning Feb. 21.
Self-Turning Snow Plow on the Delaware, Lackawanna & Western R. R.* (18) Feb. 22.
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Modern French Locomotive Practice.* Charles Rous-Marten. (10) Mar.
The Differentiation of the American Locomotive. J. C. Bayles. (20) Mar. 6.
Some Factors Affecting the Power of Locomotives.* W. F. M. Goss, M. Am. Soc. M. E. (Paper read before New England R. R. Club.) (13) Mar. 6.
The Construction of the Aspen, Wyoming, Tunnel on the Union Pacific Railroad.* W. P. Hardesty. (13) Mar. 6.
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Étude sur les Locomotives Américaines.* J. Oudet. (37) Serial beginning Oct., 1901.
Locomotive compound à grande vitesse, de la Compagnie des Chemins de fer du Nord français.* Le Fleuter. (34) Feb.
Triage Mécanique des petits colis de messageries (au départ) dans la gare de Paris-Austerlitz.* M. Pons. (38) Feb.
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The New Subway in New York City.* Charles Prelini. (11) Serial beginning Oct. 4, 1901.
The New York Rapid Transit Railway.* (13) Serial beginning Jan. 30.
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Manchester and Liverpool High-Speed Electrical Railway. F. B. Behr, Assoc. Inst. C. E. (Abstract of paper read before Glasgow Technical College Scientific Society.) (47) Feb. 8.
The Salford Corporation Tramways.* (17) Feb. 22.
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Steel Street Car Wheels. W. L. Wright. (17) Mar. 1.
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The Camps Bay, Cape Town & Sea Point Tramways.* (17) Mar. 1.
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The Double Trolley Trackless Motor Car.* Max Schiemann. (17) Mar. 1.
The Electrical Equipment of the Providence, Warren & Bristol Railroad.* (17) Mar. 1.
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Drainage Improvement by Dredging.* E. E. Watts. (Abstract of paper read before Indiana Eng. Soc.) (13) Feb. 13.
The Early History of the Memphis Sewers. A. T. Bell. (Extracts from paper read before Memphis Eng. Soc.) (14) Feb. 15.
The Sewerage Systems of Sydney, N. S. W. (14) Feb. 15.
The Septic Tank System at Fond du Lac. (14) Feb. 22.
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The Recent Epidemic of Typhoid Fever at Baraboo, Wis., and Its Probable Relation to the Water Supply.* W. G. Kirchoffer. (13) Feb. 27.
The Use of Concrete in Sewer Construction.* Harry V. Gifford. (Abstract of paper read before Mich. Eng. Soc.) (66) Mar.
The Drainage of Swamps for Watershed Improvement.* Edward S. Larned. (28) Mar.
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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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Vol. XXVIII. MARCH, 1902. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE PENNSYLVANIA AVENUE SUBWAY AND TUNNEL, PHILADELPHIA, PA.

By George S. Webster and Samuel Tobias Wagner,
Members, Am. Soc. C. E.

To be Presented May 7th, 1902.

History, and Sewer Construction.

The early history, and the construction of the sewers, connected with the work of abolishing grade crossings on Pennsylvania Ave., in the City of Philadelphia, by what is known as the Pennsylvania Ave. Subway and Tunnel, has already been described by the writers.*

It is the purpose of this paper to take up the subject where the description was left off in the previous paper, and to present such features of the completion of the work as it is hoped may be of interest to the profession.

General Description of the Work.

The following is a concise description of the work as a whole:

Beginning at the south end of the old bridge over Callowhill St., below Twelfth St., the grade begins to fall toward the west at the

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers with discussion in full will be published in *Transactions*.

* *Transactions*, Am. Soc. C. E., vol. xliv, page 1.

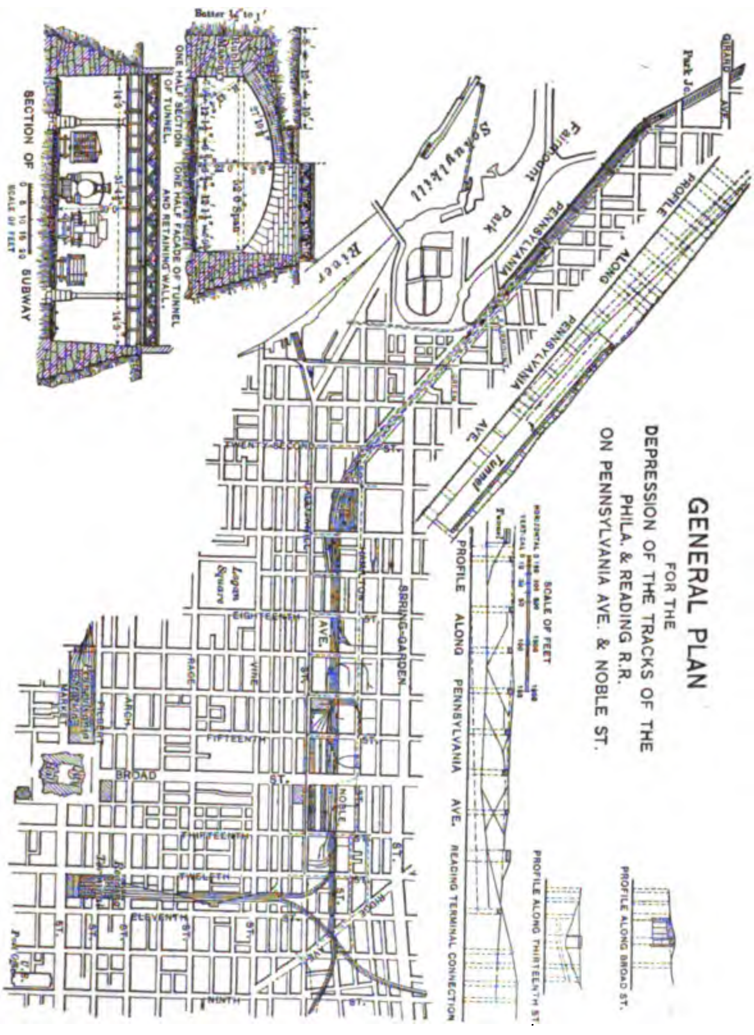

GENERAL PLAN
FOR THE
DEPRESSION OF THE TRACKS OF THE
PHILA. & READING R.R.
ON PENNSYLVANIA AVE. & NOBLE ST.
PROFILE ALONG PENNSYLVANIA AVE.
PROFILE ALONG PENNSYLVANIA AVE. READING TERMINAL CONNECTION
PROFILE ALONG THIRTEENTH ST.
PROFILE ALONG BROAD ST.
SCALE OF FEET
ONE HALF SECTION OF TUNNEL
ONE HALF FACADE OF TUNNEL AND RETAINING WALL
SECTION OF SUBWAY
SCALE OF FEET
Schuylkill
River
Fairmount
Park
PENNSYLVANIA
AVE.
Tunnel
SPRING GARDEN
NOBLE
BROAD
FIFTEENTH
EIGHTEENTH
THIRTEENTH
TWELFTH
ELEVENTH
NINTH
VINE
RACE
ARCH
Logan Square

Fig. 1.

rate of 1.46 ft. per hundred to Twelfth St. Between these points there is an iron viaduct which has been lowered from a higher elevation to meet the change in grade. A new, steel, half-through, plate-girder span, with two main girders, at 28½-ft. centers, and with a solid steel floor at right angles to them, crosses Twelfth St., and the grade of the street is slightly lowered so as to give 13 ft. headroom. From this point the grade descends at the rate of 2.5 ft. per hundred to the west, meeting the subway level west of the line of Broad St. See Fig. 1.

After crossing Twelfth St., the tracks, two in number, are supported upon earth filling between masonry retaining walls. At Thirteenth St. the most serious street change of grade occurs. On account of the rapidly descending grade of the tracks, the new level of the tracks would about cross the old level of Thirteenth St. at grade. In order to avoid this crossing it was necessary to depress Thirteenth St. about 13.5 ft. under the tracks, and run out to the present grade at Nectarine St. on the north and at Carlton St. on the south. This also changed the grades of Callowhill, Buttonwood and Hamilton Sts., all of which run east and west.

On the south side of Noble St., east of Thirteenth St., a coal yard of the Philadelphia and Reading Railway Company was lowered to the new grade of Thirteenth St., trestles were built in the yard, and track connections made from the tracks on Noble St. over the bridge at Thirteenth St. (See Contract 12.)

At Thirteenth St. the new freight yard of the railroad company commences. This extends from Callowhill St. to Noble St., and from Thirteenth St. nearly to Sixteenth St., and contains the new freight buildings (Contract 15), situated between Thirteenth and Broad Sts. At Broad St. the subway is about 25 ft. below the street level, and this depth, generally, continues to the west.

The Baldwin Locomotive Works, which are situated on the north side of the subway, between Broad and Fifteenth Sts., are connected with the depressed tracks by means of a side track on a 5% grade. On the south side a driveway, on a 5% grade, connects the subway yard with Callowhill St., and a second 5% grade connects the yard tracks with the high-level yard tracks in front of the warehouse at Sixteenth St.

On Broad St., the change of street grade at the north end of the bridge was about 4.5 ft. This was necessary in order to give a clear-

ance of 18 ft. over the main tracks. The railroad clearances throughout, with this single exception, are 20 ft. over the main tracks and at least 15 ft. over all side and yard tracks. Broad St. is the first street to cross over the subway. All streets to the west, as far as and including Twenty-first St., are carried over by means of steel bridges of plate-girder, deck type. Between Twenty-first and Twenty-seventh Sts. the streets cross the tunnel; beyond Twenty-seventh St. the only means of crossing is by foot-way bridges, Fairmount Park, with no avenues, being on the south.

The original plans contemplated the erection of a large commercial coal conveyor for the retail coal trade, located on the south side at Fifteenth St. This was abandoned, and a small coal yard constructed in its place. The original structure was covered by Contract 18; the coal yard, by Contract 49.

At Sixteenth St., in addition to the highway bridge crossing the subway, a bridge on the street level is provided to cross from the railroad yard at Sixteenth and Hamilton Sts. to a large warehouse owned by the Philadelphia and Reading Railway Company, and also to provide connection to the coal yard at Fifteenth St. It is connected with the subway tracks by means of the 5% grade already referred to. At this point the subway narrows down to the bed of Pennsylvania Ave., 80 ft. between house lines. In some cases, between this point and Twentieth St., the retaining walls on either side are built under the fronts of the buildings, the wall being on private property. In others, the wall is placed about 15 ft. from the building line, and is entirely within the bed of the street. Provision is thus made for four, and in some cases six, tracks between the retaining walls.

Between Sixteenth and Seventeenth Sts. on the north is situated the works of William Sellers and Company, Inc.; on the south, at the time the work was started, was located the works of A. Whitney and Sons. The first provision for access to these properties was by means of a hydraulic lift (Contracts 20 and 40), located on the south side of the avenue, connection being made to the north by means of an overhead bridge. The lift has been abandoned, the railway company has purchased the Whitney property, and the connection to the works of William Sellers and Company has been made by means of a 5.5% grade on the south side and an overhead bridge into their works (Contract 44).

The Baldwin Locomotive Works occupy the property on the north side of the avenue, between Seventeenth and Eighteenth Sts. Connection is made by a siding, on a 5% grade, leaving the level of the subway west of Eighteenth St. On the south side there is no railroad connection.

Between Eighteenth and Nineteenth Sts. there are no properties with railroad connections. A driveway, on steel construction, is provided for street purposes at the east end of the block on the north side.

The Twentieth St. Elevator of the Philadelphia Grain Elevator Company is situated on the south side between Nineteenth and Twentieth Sts., and the works of Stanley G. Flagg and Company on the north. The original plans provided for access to these plants by means of a hydraulic lift and a bridge similar to that at Seventeenth St. This, however, was abandoned; a 4% grade was made connecting with the grain elevator, and a connection to Flagg and Company was made from the subway level (Contract 41). In this latter case the owners have erected upon their own property a lift capable of raising a single car; the City and the railway company constructing the necessary retaining walls, making all excavation, reconstructing the buildings, and making the track connection.

The railway company owns the property between Pennsylvania Ave. and Hamilton St. and between Twentieth St. and the intersection of Hamilton St. and Pennsylvania Ave. This space was formerly occupied by a freight yard, and by engine-houses and a repair shop. It has been excavated to the level of the subway, and an engine-house, freight-house, and repair shop (Contract 25) has been built, also a locomotive coaling station (Contract 26), a 50-ton electric crane (Contract 27), and an engine turn-table. Twenty-first St. crosses this yard by means of a plate-girder, deck bridge.

On the south side of the yard is the plant of Messrs. Bement, Miles and Company, reached by connections made at the subway level between Twentieth and Twenty-first Sts. The Knickerbocker Ice Company's plant, on the south side, west of Twenty-first St., is reached by means of a 5% grade.

At the west end of this yard, the tunnel (Contract 33) begins, and extends for a distance of 2710.42 ft. It provides for four tracks. On emerging from the tunnel, the portal of the Baltimore and Ohio tunnel

is passed, some 263 ft. to the west, and, following the grade of the Baltimore and Ohio tracks, which is 1.3%, the present grade is reached at Thirtieth St., the end of the work, and 10 000 ft. from the starting point.

Alignments and Grades.

Beginning at Callowhill St., below Twelfth St., and at Station 1, the alignment is as follows:

Station 1. P. C. C. to left. Radius 395.37 ft., for 54° 59′ 50″.
Station 5 + 65.1 P. C. C. to left. Radius 536.68 ft., for 18° 29′ 10″.
Station 7 + 38.27 P. T. Tangent running west in Pennsylvania Ave.
Station 44 + 20.9 P. C. (5° curve to right). Radius 1143.42 ft., for 36° 16′ 56″.
Station 51 + 44.97 P. C. C. Radius 13189.127 ft., for 4° 44′ 26″.
Station 62 + 36.22 P. T.
Station 73 + 82.11 P. C. to left. Radius 5715.36 ft., for 3° 24′ 47″.
Station 77 + 22.58 P. T.
Station 97 + 56.66 P. C. to right. Radius 1270.39 ft., for 22° 0′.
Station 100 Connection with old tracks.

The grades are shown in Table No. 1.

TABLE No. 1.

Station.	Elevation.	Rate.	To Station.	Elevation.
0	57.33	0.00	0 + 96.92	57.33
0 + 96.92	57.33	− 1.46	5 + 44.71	50.81
5 + 44.71	50.81	− 2.5	16 + 89.21	22.20
16 + 89.21	22.20	− 0.924	23 + 16.65	16.40
23 + 16.65	16.40	0.0	24 + 91.55	16.40
24 + 91.55	16.40	+ 0.305	36 + 71.87	20.00
36 + 71.87	20.00	0.0	40 + 74.21	20.00
40 + 74.21	20.00	− 0.376	51 + 89.58	16.00
51 + 89.58	16.00	+ 0.078	76 + 98.50	18.02
76 + 98.50	18.02	+ 1.30	97 + 00	44.02
97 + 00	44.02	+ 0.833	100 + 00	46.52

Division into Contracts.

In the spring of 1896 it was decided to advertise for bids for as much of the work as possible, and it was therefore divided into contracts arranged so as to enable it to be attacked from the greatest number of points at one time without interference, and at the same time divide it so that work requiring special skill in its execution could be separated from the rest in order that the number of sub-con-

tractors would be reduced to a minimum. The following is a list of the contracts into which the work was divided:*

Contracts 1 to 6.....Sewers.

Contract 7.........Test pits.

Contracts 8 and 10..Removing old buildings.

Contract 9........Removing surplus material.

Contract 11........Temporary tracks.

Contract 12........Work of construction east of Thirteenth St.

Contract 13........Retaining walls from Thirteenth to Sixteenth Sts., except on the north from Broad to Sixteenth Sts.

Contract 14....... Excavation of the core between the retaining walls, and the construction of bridges from Thirteenth St. to the east tunnel portal.

Contract 15........Freight-houses between Broad and Thirteenth Sts.

Contracts 16, 17, 19, 21, 22, 23, 24 and 28, } Retaining walls, and the reconstruction of buildings from Broad St. to the east tunnel portal.

Contract 18........Commercial coal conveyor, Fifteenth St.

Contract 20........Hydraulic lift at Seventeenth St.

Contract 25........Freight-house, engine-house and repair shop, Twentieth St. yard.

Contract 26........Locomotive coaling station, Twentieth St.

Contract 27........Electric crane, Twentieth St. yard.

Contract 29........Subway and tunnel from the east tunnel portal to Thirtieth St.

Contract 30........Permanent tracks.

Contract 31........Interlocking signal plant.

At the time of the initial preparation of this list, Contracts 1 to 10, inclusive, had been executed, and most of them completed. Plans and specifications, therefore, were prepared for Contracts 11 to 31, inclusive, the work covered by them consisting of all the principal items except the sewerage system, and covering the new buildings, track, signal system, etc., required by the Philadelphia and Reading Railroad Company.

Detailed plans of the freight and engine-houses at Thirteenth and Twentieth Sts., Contracts 15 and 25, were prepared by the then Chief Engineer of the Railroad Company, Mr. H. K. Nichols. The plans for work on the commercial coal conveyor, hydraulic lift, locomotive coaling station, electric crane and interlocking signals, were not prepared in detail, but bids were asked upon general plans and specifications,

* A complete list of the contracts is shown in Table No. 16, appended to the paper.

the bidder to submit his detailed plans and specifications for approval. All the remainder of the work was prepared by the Bureau of Surveys, Department of Public Works of the City of Philadelphia, and approved by the Consulting Engineer of the Railroad Company, Joseph M. Wilson, M. Am. Soc. C. E.

On April 8th, 1896, the work was advertised, and May 12th was set as the time for the receipt of bids. It was thus expected that an ample opportunity would be given to prepare intelligent bids on any part of the work. During the time that the drawings, which numbered 164, were on exhibition, twenty-one contractors received prints which were prepared for their accommodation.

On May 12th, 1896, eighty-seven separate proposals were received from twenty-one different bidders, and the bids were scheduled and reported to the Director of the Department of Public Works.

The sum of the lowest bids received on this date amounted to \$3 817 961.84.

Studies for Railroad Connections.

The method of making connections to the various industrial establishments along the line of Pennsylvania Ave. was one of the most difficult problems in the design of the work. The usual block distance between cross-streets is 396 ft., and the elevation to be overcome is from 25 to 30 ft. This made it very difficult to make connections, with moderate grades leading to the subway, without interfering with the grades of the intersecting streets.

Among the methods considered was the use of the rack-rail system with grades of 10 and 12 per cent. Studies were prepared for the connections to the following points on the upper level, using this system, *viz.:*

- Warehouse at Sixteenth St.
- William Sellers and Company, and Whitney, between Sixteenth and Seventeenth Sts.
- Baldwin Locomotive Works, between Seventeenth and Eighteenth Sts.
- Baldwin Locomotive Works, between Broad and Fifteenth Sts.
- Philadelphia Grain Elevator, and Flagg and Company, between Nineteenth and Twentieth Sts.
- Knickerbocker Ice Company, west of Twenty-first St.

During the preparation of the plans, expert opinions were obtained from representative locomotive builders, and from the Engineer of the Abt Rack-Rail System in America. It was considered that heavy traffic, such as there is on Pennsylvania Ave., could be handled to advantage on a 10% grade fitted with a rack-rail.

The locomotive could be built so that it could be used on level tracks and on easy grades by adhesion, but have supplemental cylinders and cog wheels engaging in the rack where the 10% grades occurred. On a 10% grade a locomotive would have sufficient power to haul its own weight up the grade, and, in addition, a load equal to its own weight. By the addition of supplemental cylinders and cog wheels it would be possible to increase its power fourfold and more. The type of switching engine in use by the Philadelphia and Reading Railway Company, weighing about 57 000 lbs., with slight modifications, could be made to haul about 100 tons of cars and lading up a straight 10% grade. The cost of fitting up a locomotive with the necessary machinery for operating on the rack-rail was said to be from $2 500 to $4 000, depending upon the details of the plan adopted.

The cost of fuel and stores would be slightly increased, but probably not more than from 15 to 20 per cent. The additional cost of repairs was estimated at from $500 to $1 000 per annum per locomotive for the machinery for operating in connection with the rack.

The cost of the rack-rail for a single connection (say 200 ft.) would be about $2 600, including all appurtenances, and its life, as far as known, is very great.

As far as safety is concerned, the rack-rail on a 10% grade would be safer than a 5% grade without the rack, as the rack affords a means of controlling the load independent of the brakes. The rack-rail would in no way interfere with running standard cars over the tracks.

On such a system curves are especially to be avoided, if possible, and as long a radius should be used as circumstances will permit. Rack-locomotives have been built to operate on a grade of 33% combined with a curve of 398 ft. radius.

One of the four-wheeled Reading shifters in use to-day could be remodeled so as to haul a load of three or four loaded cars up a 10% grade fitted with a rack-rail, assuming each car to weigh 30 gross tons.

The principal reasons advanced for the use of the rack-rail were as follows:

1st. On account of the steep grades used, the length of the connection is very much reduced, thus largely decreasing the cost of the work of construction, and also damages to adjoining property.

2d. At many points it would have made it possible to connect with existing tracks on private property at their original level, instead of requiring a change of grade, with consequential damages.

3d. The present locomotives, with comparatively little expense, could be altered to suit the rack-rail; and the first cost of the rack-rail itself is comparatively small.

4th. The use of the rack-rail, even under disadvantageous circumstances, was found to result in a very considerable saving throughout the entire line.

The studies thus prepared did not meet the approval of the Philadelphia and Reading Railway Company, nor did they obtain the approbation of a large industrial establishment which at first was in favor of the plan. It was therefore abandoned, and the connections were made with 5% adhesion grades, together with the power lifts which have been referred to, and which in their turn were also abandoned, leaving all connections with the 5% grades, or directly from the subway level.

Sale of the Philadelphia and Reading Railroad.

On September 23d, 1896, all the property of the Philadelphia and Reading Railroad Company was sold at auction, at Thirteenth and Callowhill Sts., the City of Philadelphia, among others, protesting.

All the liabilities of the Philadelphia and Reading Railroad Company, in so far as they related to the work on the subway, were assumed by the purchasers, the newly organized company taking the name of the Philadelphia and Reading Railway Company.

Temporary Tracks.

Besides the local freight business of the Philadelphia and Reading Railroad Company to the industrial establishments on Pennsylvania Ave., it was necessary to operate the freight yards at Broad St. and at Front and Willow Sts., on the Delaware River, reached by way of Pennsylvania Ave. and Noble St. In order to provide for a continuance of this business, and at the same time to construct the subway, it was necessary to lay temporary tracks on Hamilton St. from Tenth

St. to Pennsylvania Ave. and Twenty-second St., and on Pennsylvania Ave. from Twenty-second St. to Thirtieth St. The railroad company formerly had four tracks on Pennsylvania Ave.

On August 10th, 1896, the work of constructing the tracks on Ham- St. between Tenth and Twenty-first Sts. was begun, the tracks being laid with new material. The street paving was removed and stored for future use, but a large portion of it was of cobble, which was never relaid. The subgrade was excavated so as to bring the top of the rail about level with the curb. Broken stone or approved slag ballast to a depth of 6 ins. was placed beneath the ties, which were of white, rock or chestnut oak, or yellow pine of good quality. The two ties at each joint were first-class, 8½ ft. long, 7 ins. thick, and not less than 7 nor more than 14 ins. on the broadest face. The remainder could be second-class, in which the face was not less than 6 ins. Interlaced ties were used for all turn-outs and cross-overs. Fourteen ties were used to each 30-ft. rail.

All new rails were of the Philadelphia and Reading standard 79-lb. section. The chemical composition was specified as follows:

Carbon	0.55 to 0.60
Silicon	0.15 to 0.20
Manganese	1.10 to 1.30
Sulphur	0.069
Phosphorus	0.06

Rails having carbon below 0.53 or above 0.65 were rejected.

The drop-test required that one test be made from each heat, and that 90% of the specimens must stand without breaking under a weight of 2 000 lbs. with a 20-ft. drop, and with the rail supported 3 ft. between centers.

It was the intention, in specifying this quality of rail, to take it up upon the completion of the temporary tracks, and use it for sidings and yard tracks in the permanent work, if it passed the physical inspection after being in service.

Most of the industrial establishments backing on Hamilton St. were connected to this temporary track system. At Sixteenth St. a connection was made with the tracks in Callowhill St., terminating in temporary freight-houses at Thirteenth and Callowhill Sts., and

arranged so as to occupy only half of the block between Broad and Thirteenth Sts.

West of Twenty-first St., Pennsylvania Ave. was widened on the south side as far west as Twenty-fifth St., to provide for the new alignment of the tunnel, and between Twenty-second and Twenty-fifth Sts. the old tracks were shifted to the south, so as to allow the north abutment of the tunnel to be constructed. After the north tunnel wall was built, the tracks were shifted to the north side of the wall, where they remained until traffic was running on the permanent tracks through the tunnel.

It was the intention to use as much of the old rail as was possible in the construction of the temporary tracks, and, therefore, prices were asked in the proposal for doing the various classes of work, as given in Table No. 2.

At street crossings and other places where the tracks were crossed by teams or foot traffic the tracks were planked with 3-in. yellow pine planking on 1-in. blocking over the ties, so as to form a passageway.

TABLE No. 2.—PRICES. TEMPORARY TRACKS. CONTRACT 11.

Classification.	Price.
New material throughout	\$2.05 per linear foot.
Second-hand rails, new ties	1.85 " " "
Old rails, all other material new	1.25 " " "
Old rails and ties, other material new	0.99 " " "
New frog and switch	150.00 each.
New single and double slip-switches	650.00 each.
New crossings—steam or trolley	250.00 each.
Old switches, new ties and ballast	75.00 each.
Old single or double slip-switches	250.00 each.
Old crossings	75.00 each.
Lumber for planking	30.00 per M. ft. B. M.
Temporary freight-sheds	9 700.00
Shifting trolley tracks	1.25 per linear foot.
Drainage, and removing old buildings	3 700.00

All track work was made and paid for by the linear foot, measurement being made once by passing through switches on the main track, and again by starting from the point of the switch and measuring out on the turn-out.

The contract was awarded to P. McManus, and the work was carried on as the progress of the work on the subway demanded. It was completed on June 12th, 1898. In all, 49 933 ft. of track of all

grades were laid, 194 switches and crossings were placed in the line, and the total amount paid to the contractor was $144 028.99.

Retaining Walls and Underpinning.

Immediately after work was begun upon the temporary tracks, the several contractors for the underpinning of buildings and the construction of retaining walls between Thirteenth St. and the east portal of the tunnel were ordered to begin work. This work was divided into nine contracts, numbered as follows, 13, 16, 17, 19, 21, 22, 23, 24 and 28, and each contract generally embraced the work between two adjacent cross-streets, that is, from the west house line of one street to the west house line of the next, and on both sides of the avenue, and included the adjustment of the buildings and the construction of the retaining walls. Each contract also covered both bridge abutments on the street to the west.

The first operation was either to underpin the walls of the adjacent buildings or to reconstruct their fronts. The method used was shown on the contract drawings for each side of the avenue. These drawings usually were three in number, showing as follows:

1st. The conditions existing before any work was done.

2d. Any temporary work which was necessary.

3d. The work as it was to be completed.

Table No. 4 is a list of the buildings adjacent to the work, giving the method of treatment.

TABLE No. 3.

Between streets.	Side.	Name of building.	Treatment.
Broad to 15th........	North.	Baldwin Locomotive Works.	None required.
15th to 16th..........	North.	Four-story machine shop.	Reconstruction.
" " "	South.	Six-story warehouse.	Underpinning.
16th to 17th..........	North.	Large machine shop.	Underpinning.
" " "	South.	Car-wheel foundry.	Underpinning.
17th to 18th..........	North.	Baldwin Locomotive Works.	Underpinning.
" " "	"	" " "	Reconstruction.
" " "	South.	No buildings.	....
18th to 19th........ .	North.	Spring works.	Reconstruction.
" " "	South.	Row of small dwellings.	Removed.
19th to 20th..........	North.	Foundry and shop.	None required.
" " "	South.	Grain elevator.	Alterations made by owners.
20th to 21st..........	South.	Machine shops and foundry.	Reconstruction.

Underpinning.

Fig. 2 shows a typical section of the retaining wall, with the underpinning of the building on the north side of the subway, between Sixteenth and Seventeenth Sts.

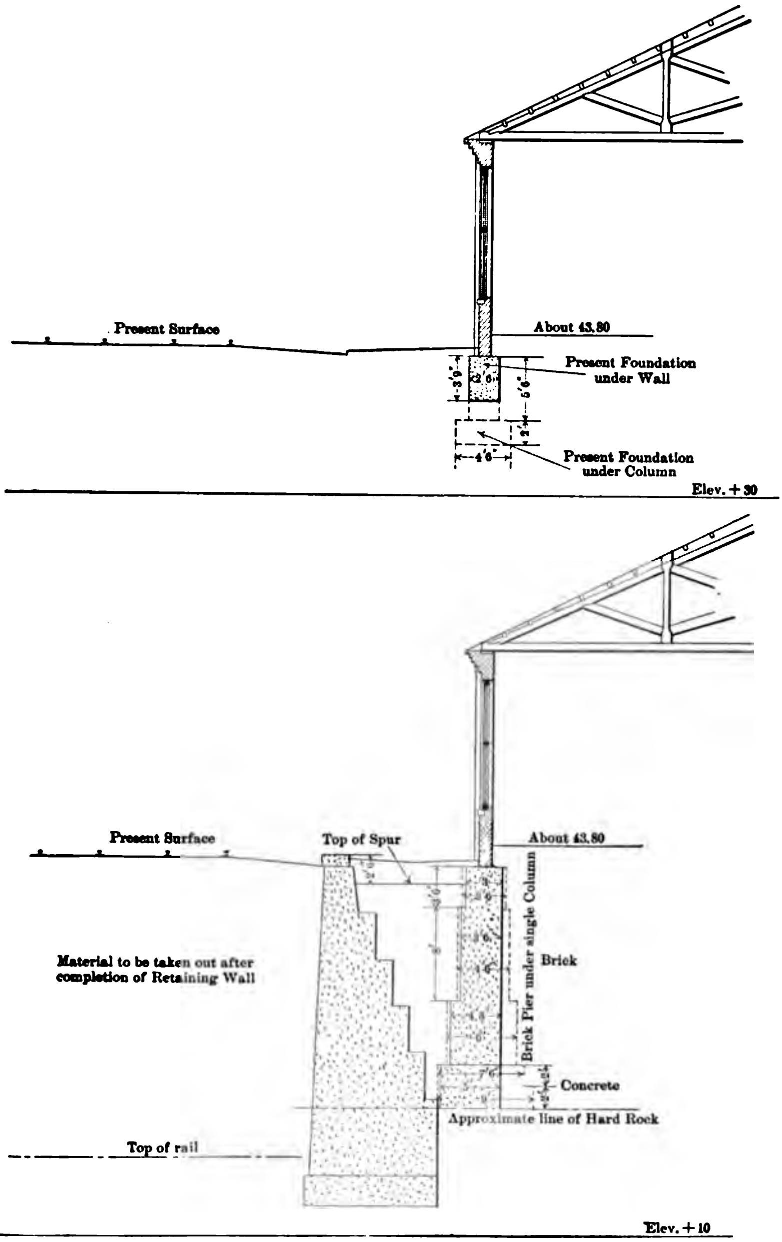

Present Surface
About 43.80
Present Foundation under Wall
Present Foundation under Column
Elev. + 30
Present Surface
Top of Spur
About 43.80
Material to be taken out after completion of Retaining Wall
Brick
Brick Pier under single Column
Concrete
Approximate line of Hard Rock
Top of rail
Elev. + 10

Fig. 2.

Wherever it was very important not to enter upon private property, or where the conditions of the existing walls made underpinning cheaper than their removal, this method was always carried out. No specific method for doing this work was described in the specifications, the contractors merely being required to do it with the utmost care, and in the best manner, subject to the approval of the Chief Engineer; properly supporting the parts exposed through the excavation in such a manner as to prevent any damage to the building, machinery, or plant, either during the operation of the work or subsequent thereto. The detailed methods of shoring and making the excavations, therefore, were left to the ingenuity of the contractor for each special case.

Fig. 1, Plate III, shows the method used for underpinning the steel columns in the front of the building of Messrs. William Sellers and Company, on the north side of Pennsylvania Ave. between Sixteenth and Seventeenth Sts. The columns supported the ends of the runway of a 50-ton traveling crane, spanning one of the shops and running at right angles to the avenue. The columns are in the front wall, which is of brick, 2 ft. thick and about 20 ft. high. The footing course was of rubble masonry laid in cement mortar and resting upon a bed of clay and gravel about 25 ft. thick, which rested on the rock. Small excavations were made under each column, and transverse wooden beams were slipped under its granite base and wedged up on a pair of longitudinal wooden stringers just outside of the footing. The excavation was then enlarged, and batter posts were placed in its sides. These carried the loads to sill pieces laid outside the limits of a trench which was carried down under the center of the wall. The excavation was sheathed and braced as shown in Fig. 3. A concrete footing was then placed upon the rock, and a vertical strut of 12 x 12-in. yellow pine was placed upon it, and wedged with steel wedges beneath the granite base. A brick pier, laid in Portland cement mortar, was then built up around this strut, and wedged up with a large number of steel wedges beneath the granite base. The intervening walls between the columns were treated in a simpler manner. Alternate sections, from 8 to 12 ft. in length, were excavated, shored and braced up, and then built up from the concrete foundation with selected flat stone laid in Portland cement mortar and wedged tight against the footing-course. The floor of this shop is a bed of concrete 12 ins. thick, and the large machine tools rest upon it without further foundations, many of them being immediately

PLATE III.
PAPERS AM. SOC. C. E.
MARCH, 1902.
WEBSTER AND WAGNER
ON PENNSYLVANIA AVENUE SUBWAY.

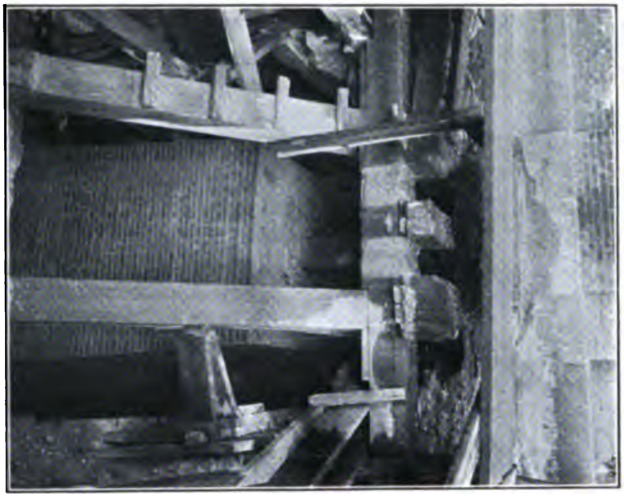


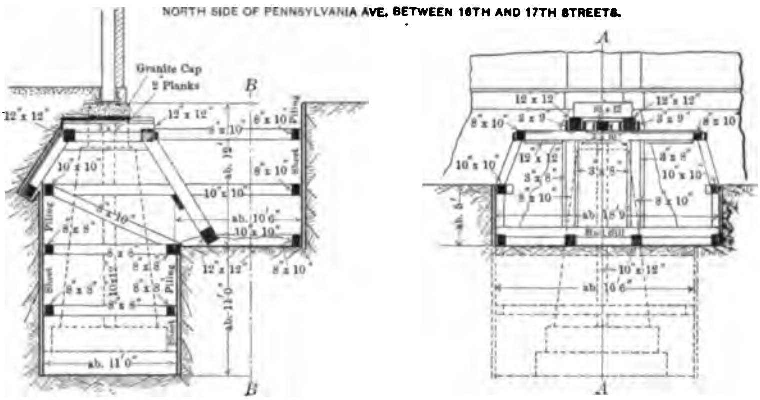
Fig. 1.—Underpinning Masonry.

Fig. 2.—Eighteenth Street Bridge.

adjacent to the front wall. A very slight settlement of these tools would throw them out of adjustment, but no complaint of any settlement, whatever, was received, nor were any cracks visible in the front wall.

This method of underpinning was carried out successfully beneath the entire front of the six-story warehouse at Sixteenth St.; the eastern half of the Whitney Car Wheel Company, on the south side between Sixteenth and Seventeenth Sts.; the boiler-house and forge shop of the Baldwin Locomotive Works, between Seventeenth and Eighteenth Sts., and a large number of very heavy buildings on the line of Thirteenth St. In each case, the specifications provided for the general method

SYSTEM OF SHORING AS APPLIED FOR UNDERPINNING COLUMNS
IN THE BUILDING OF WILLIAM SELLERS & CO.
NORTH SIDE OF PENNSYLVANIA AVE. BETWEEN 16TH AND 17TH STREETS.



SECTION *A-A* SECTION *B-B*

FIG. 3.

of the work, without regulating the details. In all cases, except for the work on Thirteenth St., the price for the underpinning was included in a lump sum for building the retaining walls and reconstructing the buildings in each block. On Thirteenth St., the price was by the cubic yard. A special price for additional underpinning, however, was bid under each contract, so as to provide for unforeseen conditions.

Reconstruction of Buildings.

Wherever it was not found expedient to underpin the buildings, the fronts were removed and reconstructed. This method was adopted:

1st. When the existing condition of the front wall was so bad as to make underpinning hazardous and expensive.

2d. In cases where the main retaining wall had to be constructed with its face on the same line as the face of the building, the character of the wall requiring the use of derrick stone which could not be placed in underpinning.

3d. Where, for any reason, it was cheaper to remove the front than to underpin.

The specifications uniformly provided that a temporary front be constructed, inside the present front, made of hemlock scantling, covered inside with hemlock boards, Neponset roofing paper and second-quality white pine fencing vertically over all. The existing door and window frames were then to be removed from their places in the present wall, set in the temporary front, and the whole made weather-tight. The floor joists and other structural parts of the building were then supported as shown on the plans for each particular case, and the front wall was removed. Then the excavations were made for the retaining wall or the new foundation, and the new walls were constructed, the window and door frames being replaced as the building progressed.

The contractor on each contract bid a lump sum for removing all machinery, goods or stores which were in the way, and for restoring them to their original positions.

Fig. 4 shows a typical cross-section of such building reconstruction.

Retaining Walls.

The retaining walls were in all cases constructed of rubble masonry under the following general specifications:

"All retaining walls shall consist of first-class Conshohocken or other approved stone of good shape and good flat beds; no stone having less bed than face; laid on their broadest faces as rubble work in Portland cement mortar.

"In walls of 5 ft. thickness or less, the stones shall average from 6 to 8 cu. ft. each, and the length of the headers shall be two-thirds of the thickness of the wall. In walls over 5 ft. thick the stones shall average 12 cu. ft. each, and headers shall be at least 4 ft. long. Generally, no stones of less than 4 cu. ft. shall be used, except for filling the interstices between the larger stones. At least one-fifth of each face of all the walls shall be composed of headers placed so that those on one face come between those on the other; and, where the thickness of the walls is such that the headers from opposite faces do not overlap, stones not less than 4 ft. long shall be set transversely in the heart of the wall to complete the bond.

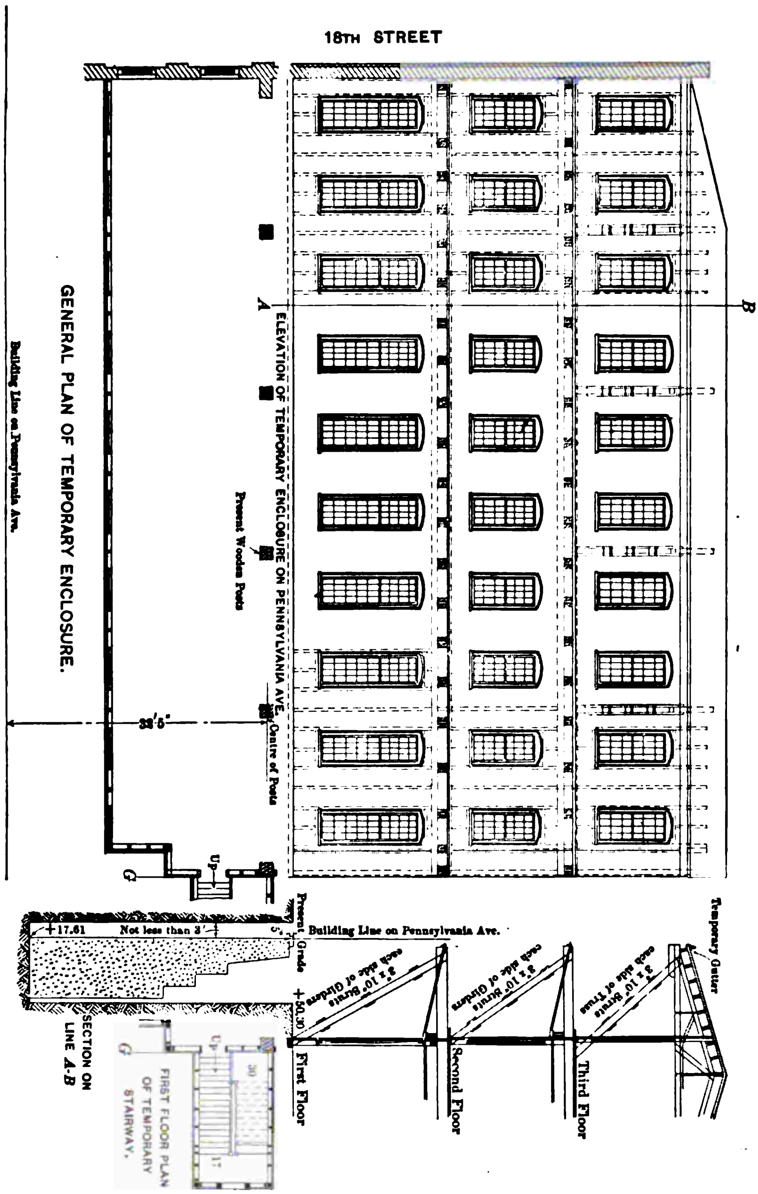

18TH STREET
GENERAL PLAN OF TEMPORARY ENCLOSURE.
ELEVATION OF TEMPORARY ENCLOSURE ON PENNSYLVANIA AVE.
Building Line on Pennsylvania Ave.
Present Wooden Posts
Centre of Posts
33'5"
A
B
G
Up
+17.61
Not less than 3'
Present Grade
+50.30
Building Line on Pennsylvania Ave.
each side of Girders
3" x 10" Struts
each side of Truss
Temporary Gutter
First Floor
Second Floor
Third Floor
SECTION ON LINE A-B
FIRST FLOOR PLAN OF TEMPORARY STAIRWAY.

FIG. 4.

"These walls must be built accurately to lines and levels given, and all exposed faces of the stone must be true and straight, and without prominent projections of the quarry faces. The mortar in all joints on exposed faces shall be kept back one inch.

"Selected stone shall be used at all angles, and shall be neatly pitched to true lines and laid on hammer-dressed beds. At all angles 1½-in. draft lines will be required.

"Grout shall be used in place of mortar, wherever directed by the Chief Engineer.

"The face and back of the wall shall be carried up together, over the whole wall, in approximately the same total height, except where otherwise specified.

"In rock-faced work, the faces of the stones shall have uniform projections not exceeding 3 ins., and in rough-pointed work not more than 1 in. beyond the neat lines, and in both cases they shall be pitched to a straight line at all the joints.

"The joints between all stones on the back of all retaining walls and abutments shall be carefully and thoroughly washed with Portland cement mortar so as to make the walls water-tight.

"In cases where rock adjoins the back of the wall, the wall is to be built up tight against the rock, and the joint thoroughly grouted with Portland cement grouting.

"All walls and abutments are to be thoroughly drained, wherever directed by the Chief Engineer, by means of 4-in. cast-iron pipe, built in the wall, or by openings left, as may be ordered. Wherever necessary, tile or French drains of broken stone, 18 × 18 ins., as shown on the drawings, shall be placed at the back of the wall. These drains and pipe will be paid for, per linear foot, at the price given in the proposal for such work.

"All pointing shall be done with Portland cement mortar of an approved brand. The surfaces of all stone shall be thoroughly cleaned, the joints scraped out to the depth of at least an inch, and the whole thoroughly wetted before pointing is commenced."

The mortar, grout and cement used were required to meet the following requirements:

"In all cases where Portland cement mortar is specified, the mortar shall be composed of 1 part of Portland cement to 3 parts of sand.

"Mortar taken from the mixing box, and moulded into briquettes, 1 sq. in. in cross-section, shall develop the following ultimate tensile strength:

AGE.	STRENGTH.
7 days (1 day in air, 6 days in water) 1 part of Portland cement to 3 parts of sand	100 lbs.
28 days (1 day in air, 27 days in water) 1 part of Portland cement to 3 parts of sand	150 "

FIG. 1.—ERECTION OF BROAD STREET BRIDGE.

FIG. 2.—ERECTION OF FIFTEENTH STREET BRIDGE.

"Grout made of Portland cement shall be composed of 1 part of Portland cement to 2 parts of sand, except where the foundations are wet, when the quantity of sand shall be diminished, making the proportions 1 part of Portland cement to 1½ parts of sand, which shall be used in the foundation masonry up to the neat lines if required.

"Portland cement shall have a specific gravity of not less than 3, and shall leave, by weight, a residue of not more than 1% on a No. 50 sieve, 10% on a No. 100 sieve, and 30% on a No. 200 sieve.

"Pats of neat cement, ½ in. thick, with thin edges, immersed in water, after 'hard set,' shall show no signs of 'checking' or disintegration.

"It shall require at least 30 minutes to develop initial set.

"Briquettes of cement, 1 sq. in. in cross-section, shall develop the following ultimate tensile strengths:

AGE.	STRENGTH.
24 hours (in water, after hard set)	175 lbs.
7 days (1 day in air, 6 days in water)	450 "
28 days (1 day in air, 26 days in water)	550 "
7 days (1 day in air, 6 days in water), 1 part of cement to 3 parts of standard quartz sand	160 "
28 days (1 day in air, 26 days in water), 1 part of cement to 3 parts of standard quartz sand	220 "

"All cements shall meet such additional requirements as to 'hot water,' 'set,' and 'chemical' tests as the Chief Engineer shall determine. The requirements for 'set' may be modified where the conditions are such as to make it advisable."

Table No. 4 shows the average results of the tests of the cement used.

Fig. 5 shows a typical section of retaining wall with standard coping and French drain and weeper. Reduced heights were usually designed by cutting the standard section at the desired point.

Wherever possible, the faces of all walls were given a batter of ½ in. per foot. Where the face of the wall was on a building line, and in a few other cases, the batter was omitted.

The neat line was generally 18 ins. below the top of the rail. Unless otherwise ordered, the bed of the foundation was specified to be 5 ft. below the top of the rail in earth and soft rock, and 3 ft. below in hard rock. On lump-sum contracts, any masonry below these lines was paid for as additional masonry at the price bid.

Bridge Abutments.

Under the same contracts, and at the same time that the retaining walls were built, the abutments of all bridges were constructed. They were on the same lines as the walls, and were built practically in

the same trench. The contract required the construction of temporary wooden bridges over the trenches on the lines of the cross streets. The masonry was constructed beneath these bridges up to as high an elevation as possible, their completion being included in the contract for the construction of the bridges. These temporary bridges, therefore, were used over the two abutments of each cross-street until the core was removed and the bridges constructed. They were paid for at a unit price for the lumber, and generally cost about $250 each.

The abutments were constructed of rock-faced, coursed, ashlar masonry with rubble backing; and were laid in Portland cement mortar of the same proportions as described under "Retaining Walls." In all cases, a straight vertical joint was made between the retaining walls and the bridge abutments. The standard side and head clearances are shown in Fig. 6.

The specifications for the ashlar were as follows:

"In range ashlar the stones shall be equal to the best Stockton or Clearfield County stone. If other stones are intended to be used, specimen 6-in. cubes, properly labeled, must be submitted, and that accepted shall be considered as the standard. The stones shall be laid in regular courses with bonds on the face not less than 12 ins.; they shall be uniform in color, and free from stains. All mortar and grouting that has run out over the faces shall be washed off clean before it has set.

"If there be nothing shown or noted on the drawings, or stated in the clause relating to the work in particular of these specifications to the contrary, the faces of the headers in each course shall form at least one-fifth of its face.

"The height of the courses shall not exceed 30 ins., nor be less than 18 ins. The stones shall be dressed for ¼-in. joints, true to the proper lines, out of wind, with parallel beds and vertical joints; at the latter joints they shall be dressed at least 6 ins. back of the face, and the beds shall be tooled over their entire surfaces.

"The headers shall have at least as much width of face as rise, but not less than 18 ins., and they shall not be less than 4 ft. long.

"The stretchers shall have as much bed as rise, but not be less than 18 ins. wide; they shall not be less than 4 ft. long, and shall not break joints on headers.

"The backing shall be of coursed rubble masonry, well bonded with the ashlar and in itself."

All work on the bridge abutments was paid for by the cubic yard, *viz.*, excavation and masonry, including the rubble backing.

TABLE No. 4.—TESTS OF CEMENT USED ON PENNSYLVANIA AVENUE SUBWAY AND TUNNEL.*

	Fineness. Percentage of Residue on Sieve.						Time of Setting, in Minutes.				Tensile Strength, in Pounds.																					
											Neat.												Three parts standard sand.									
Portland Cement.	No. 50.		No. 100.		No. 200.		Initial set.		Hard set.		24 hours.		7 days.		28 days.		2 months.		3 months.		4 months.		7 days.		28 days.		2 months.		3 months.		4 months.	
	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.	No. of tests.	Average.
Vulcanite	53	0.5	53	7.0	49	20.1	60	124	61	350½	101	304	101	714	90	793	6	796	15	806	13	773	101	239	90	292	7	318	14	328	13	334
Giant	71	0.8	71	7.7	69	17.8	65	40½	66	132¾	151	284	151	452	139	528	15	535	27	577	23	608	151	177	139	249	15	306	27	305	23	321
Atlas	15	0.5	15	9.2	15	25.1	36	68	36	339½	48	401	48	671	38	766	2	845	6	817	5	829	48	194	38	274	2	300	6	315	5	319
Alpha	12	0.9	12	9.5	12	23.8	4	190½	4	426½	24	381	24	675	24	759	4	808	7	828	5	830	24	247	21	289	4	326	7	318	5	344
Egypt	1	0.5	1	12.6	1	22.2	....	....	....	....	1	281	1	474	1	584	..	....	..	....	1	760	1	174	1	239	..	....	..	....	1	273
Heyn	2	0.4	2	7.2	2	17.8	8	100	8	286¾	8	292	8	452	8	502	..	....	..	....	..	....	8	158	8	212	..	....	..	....	..	....
Saylor's	1	0.0	1	6.8	1	20.2	3	77¾	3	435¾	3	282	3	526	3	714	..	....	..	....	..	....	3	177	3	236	..	....	..	....	..	....
Totals and averages.	155	0.7	155	7.7	149	19.8	176	81½	178	268	336	314	336	579	308	656	27	656	55	698	47	704	336	208	308	267	28	311	54	314	47	326
Natural Cement.	Fineness. Precentage of Residue on Sieve.						Time of Setting, in Minutes.				Neat.												Two parts standard sand.									
Akron	....	....	....	....	....	....	7	8¼	7	25¾	7	186	7	271	7	396	..	....	..	....	..	....	7	134	7	223	..	....	..	....	..	....
Cumberland	7	3.8	7	14.4	5	28.2	18	12¾	18	66	18	129	18	253	18	323	1	360	2	362	..	....	18	142	18	244	1	223	2	371	..	....
Improved Union	4	2.4	4	10.0	4	20.4	20	4¼	20	44¼	21	166	21	219	16	299	..	....	..	....	1	358	21	150	16	222	..	....	..	....	1	335
Improved Anchor	1	3.5	1	18.7	1	29.1	2	23	2	146	2	114	2	209	2	392	..	....	..	....	..	....	2	128	2	217	..	....	..	....	..	....
Totals and averages.	12	3.3	12	18.3	10	25.2	47	8¾	47	54	48	153	48	239	48	330	1	360	2	362	1	358	48	143	48	231	1	223	2	371	1	335

* Compiled from reports of the Inspector of Cements, Bureau of Surveys.

Cost of Underpinning, Reconstruction of Buildings and Retaining Walls.

A summary of the cost of the work under these headings is given in Table No. 5.

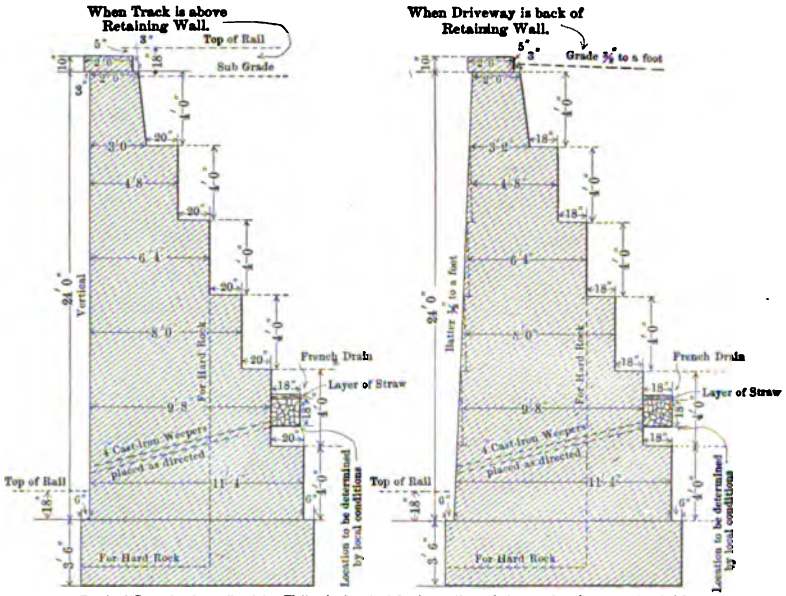
TABLE No. 5.

Contract No.	Description.	Cost.
13........	Retaining walls from 13th to 15th Sts., except on north side from Broad to 15th Sts., including both abutments at Broad St. bridge, south abutment of 15th St. bridge and excavation for lowering water mains on Broad St. E. D. Smith & Co., Contractors......	$84 995.66
16........	Retaining walls on north side from Broad to 15th St., including the north abutment of 15th St. bridge. M. McManus, Contractor.	24 295.21
17........	Retaining walls between 15th and 16th Sts., including reconstruction of buildings on north side, underpinning of warehouse on south side, abutments of railroad high-level bridge and highway bridge on 16th St. P. H. Flynn & Co., Contractors..............	100 741.82
19........	Retaining walls between 16th and 17th Sts., including underpinning of buildings on north and south sides, abutments of railroad bridge between 16th and 17th Sts. and highway bridge at 17th St. (This contract not completed on south side. See Contract 44 for balance of cost.) P. H. Flynn & Co., Contractors.........	108 018.49
44........	Completion of masonry walls and abutment on south side between 16th and 17th Sts. E. D. Smith & Co., Contractors..............	13 444.48
21........	Retaining walls between 17th and 18th Sts., including underpinning of buildings at east end on north side and reconstruction of building at west end on same side, construction of coal pit on north side and abutments of highway bridge on 18th St. P. H. Flynn & Co., Contractors..	105 557.70
22........	Retaining walls between 18th and 19th Sts., including reconstruction of buildings on north side and abutments of highway bridge on 19th St. P. H. Flynn & Co., Contractors.....................	72 102.12
23........	Retaining walls between 19th and 20th Sts., including abutments of highway bridge on 20th St. E. D. Smith & Co., Contractors.	68 812.63
41........	Construction of pit for hydraulic lift on north side between 19th and 20th Sts., including bridge over connection, and reconstruction of buildings. E. D. Smith & Co., Contractors,............	19 904.20
24........	Retaining wall on east side of 20th St. from Pennsylvania Ave. to Hamilton St.; on south side of Hamilton St. from 20th St. to east tunnel portal; reconstruction of buildings and construction of retaining walls on south side from 20th to 21st Sts.; both abutments of 21st St. bridge. P. H. Flynn & Co., Contractors.......	145 782.61
28........	Retaining walls on the south side from the line of 21st St. to the east portal of the tunnel. E. D. Smith & Co., Contractors......	16 264.20
52........	Construction of coal-hopper pit and building on the south side between 20th and 21st Sts. Stacy B. Opdyke, Contractor..........	4 081.69
	Total work of reconstruction of buildings, underpinning and retaining walls....................................	$763 970.81

The following is a list of the most interesting unit prices on the contracts mentioned in Table No. 5:

Ashlar for bridge abutments, per cubic yard....................$9.50
Additional rubble masonry, per cubic yard..................... 6.50
Additional brick underpinning, per cubic yard..........$9.00 to 20.00
Additional rubble underpinning, per cubic yard.......$9.00 to 20.00
No. 4 railing, per linear foot............................... 2.00
No. 6 railing, per linear foot..... ....$0.95 to 1.05
French drain, per linear foot................................ 0.10
4-inch cast-iron weepers, per linear foot.................0.25 to 0.70

STANDARD SECTIONS FOR VERTICAL AND BATTERED RETAINING WALLS
PENNSYLVANIA AVENUE SUBWAY AND TUNNEL.



For the different heights of Retaining Walls, the Standard Sections will merely be cut off to the appropriate heights measuring from the top downward, and the footing not less than 3 ft. 6-ins. high for ground and soft rock will have 6-in. projections front and back. From the line of hard rock down the back of retaining wall will be vertical and the footing, 2 ft. 6 ins. high, will have no offsets back: the Standard Section will be maintained above this rock line.

FIG. 5

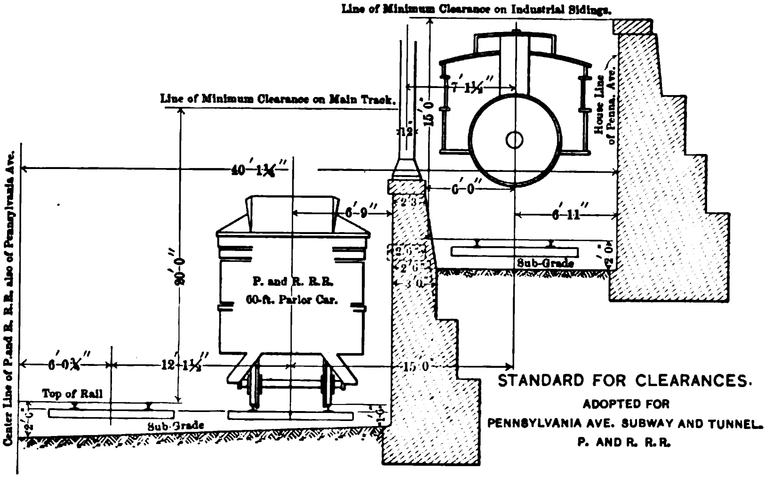


FIG. 6.

In the above-mentioned total cost of the retaining walls, bridge abutments, and the underpinning and reconstruction of buildings from Thirteenth St. to the east portal of the tunnel, which amounted to $763 970.81, the piers for the bridges, a number of short lengths of retaining walls between the main walls, and in several cases the railings, were not included. The work which was thus omitted was all covered under Contract 14.

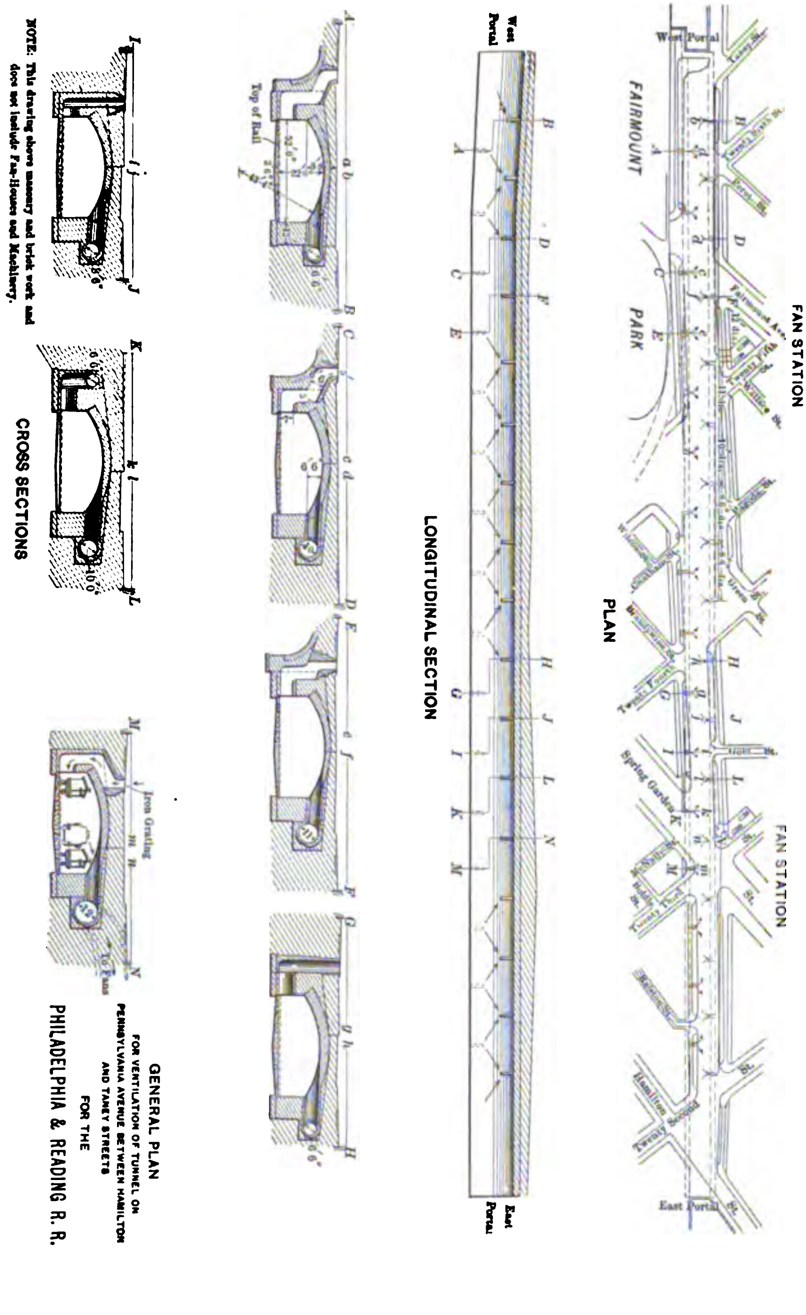
Proposed Tunnel Ventilation.

Contract 29, which covered the work of the construction of the tunnel, included a system of conduits designed for the artificial ventilation of the tunnel. This work was part of a complete system to meet the requirements of heavy traffic through the tunnel which was planned as 52 ft. wide and 2 913 ft. long.

Two fan stations (see Fig. 7) were proposed, situated so as to divide the length of the tunnel into four almost equal sections, the stations being located on the north side of the tunnel. In each station there were to be provided two fans, 20 ft. in diameter, drawing the foul air and gases from the tunnel through openings at intervals of about 150 ft., leading from the roof of the tunnel to the conduits which were also located on the north side of and parallel to the tunnel.

The grade of the conduits was arranged so that any condensation would run to the fan stations, where provision was made to care for it. The conduits were 11 ft. in diameter at the fan stations, decreasing to 6½ ft. at the ends. It was the intention to drive the fans by electric motors, and to discharge into ornamental stacks high enough to prevent any inconvenience to surrounding properties. The conduits at the stations were arranged so that the fans could be connected to either line of conduits, or so that one fan could exhaust from both lines of conduits in case of a break-down or repairs being made. Each fan was to have had a capacity of 600 000 cu. ft. per minute, or about one-fifth of the entire contents of the tunnel. It was thus expected that the entire contents would be replaced every five minutes.

On the south side of the tunnel, and placed midway between the suction openings, fresh-air intakes were to be provided, 150 ft. apart, each with an effective area of 35 sq. ft. They were to be connected to the tunnel at the level of the rail, and the openings into the street were to have been placed in the grass plats between the sidewalk and



GENERAL PLAN
FOR VENTILATION OF TUNNEL ON
PENNSYLVANIA AVENUE BETWEEN HAMILTON
AND TANEY STREETS
FOR THE
PHILADELPHIA & READING R. R.

FIG. 7.

the curb. If necessary, automatic shutters were to have been provided to prevent any gas from escaping into the street. These would close when there was any pressure of air from the tunnel. The power to operate the motors at the fans was to be obtained from a power-house situated on Pennsylvania Ave., between Eighteenth and Nineteenth Sts., which was also to supply power to the hydraulic lifts located at Seventeenth and Nineteenth Sts.

The Tunnel.

On May 28th, 1896, a conference was held at the office of the Mayor, Hon. Charles F. Warwick, between the officials of the City and of the Philadelphia and Reading Railroad Company, at which the City was asked to pay part of the cost of maintaining and operating the ventilation of the tunnel and the hydraulic lifts.

The agreement reached was to abandon the artificial system of ventilation in the tunnel, shorten its length, and introduce openings from the roof of the tunnel to the street.

These changes required a modification of the plans and specifications of the work on the tunnel. Work was at once begun on the plans, and, after several conferences, the revised plan was approved on August 3d by the Director of the Department of Public Works, and on August 6th by the President of the Philadelphia and Reading Railroad Company. Contract 29 was abandoned, and the work was re-advertised on August 15th, 1896, for proposals to be received on September 1st. Proposals were received on the latter date, on the new plans, under Contract 33.

Comparing the relative costs of the work, by figures based on the approximate quantities given in the specifications, there was a saving of about $220 000. Contract 29 did not include any work upon the fan stations for the ventilation system, nor the cost of the land for the same.

In the preparation of the plans for the new tunnel, it was necessary to make a large number of studies, as the interests of the City required as few openings as possible, and the Railroad Company desired practically an open cut. The conference above mentioned decided that each opening should be 10 ft. in width and of sufficient length to obtain 300 sq. ft. of net area. As the arch of the tunnel was designed of brick, it was decided that it would be impracticable to make the

FIG. 1.—TUNNEL ARCH AND CENTERS.

FIG. 2.—INSIDE OF THE TUNNEL.

construction of these openings of brick. The plans, therefore, which were approved, terminated the brick arch at each end of the ventilation opening, carried up the side walls, and spanned the tunnel with steel girders and beams, between which the opening is framed.

On account of the action of the fumes from the locomotives upon the steel-work, it was considered of the first importance that every portion of the metal-work in these openings should be thoroughly protected. The following extracts from the specifications indicate clearly how this was done:

"These openings are to be constructed of a steel frame replacing the arch of the tunnel. Generally, four lines of plate girders, resting upon granite bridge-seats in pockets upon the side-walls of the tunnel, support lines of 12-in. I-beams, between which brick arches are to be constructed carrying the weight of the street above. The opening, 78 ft. long, has six lines of plate girders. The beams to be thoroughly tied together with tie-rods, as shown on the drawings.

"The spaces between the girders facing the openings shall be built up with a 9-in. brick wall, which shall have certain arches for manholes, as shown. These manholes shall be compactly built up, upon the completion of the work.

"The necessary retaining walls, upon the arch of the tunnel and surrounding the openings, shall be constructed as shown. The size of stone in these walls shall be subject to the approval of the Chief Engineer. The walls above the street level shall have a rustic combing of stone, carefully set.

"The metal-work shall be protected from the action of the locomotive fumes by plastering the main girders, where they cross the openings, with two coats of Portland or other approved cement mortar (mixed in the proportion of 1 part of cement to 1 part of sand). The first coat shall be about 1 in. thick, and, before the second is applied, the girder shall be covered with metal, plastering lath, or wire, of a quality to be approved by the Chief Engineer. The total thickness of the plastering shall be 2 ins. when finished.

"The under side of the main girders, not beneath the ventilation opening proper, shall be protected by a covering of 4-in. I-beams attached to the bottom flanges of the main girders, and supporting in turn a ceiling of terra cotta fire-proofing material arranged so as to cover the bottom flanges of the 4-in. I-beams in the manner shown on the drawings. The detail of the terra cotta to be subject to the approval of the Chief Engineer.

"This terra cotta ceiling to be set in Portland cement mortar (1 part of cement to 2 parts of sand) and filled up to a level on top with concrete composed of 1 part of Portland cement, 3 parts of

sand and 5 parts of furnace slag, free from dust or dirt, and broken so as to pass through a 1-in. ring in any direction. The under side of the terra cotta material to be plastered with Portland cement mortar (1 part of cement to 2 parts of sand) 1 in. thick.

"The terra cotta work of the protective ceiling, including the concrete and the cement plastering, in place complete, as specified above, shall be paid for by the square foot at the price given in the proposal for the terra cotta protective ceiling or plastering of the main girders."

Tunnel and Open Subway at West End.

On January 12th, 1897, the contract for constructing the tunnel and the open subway at the western end of the work was awarded to Messrs. E. D. Smith and Company, and work was begun by them on March 8th, 1897. This contract was known as No. 33.

At this time the temporary tracks were constructed upon the south side of Pennsylvania Ave. from Hamilton to Twenty-fifth Sts., where they connected with the regular alignment. This allowed of the construction of the north wall of the tunnel from Hamilton St. to a point west of Twenty-sixth St., as well as the north retaining wall of the open subway from the last-named point to the end of the work at Thirtieth St. These walls were constructed in an open trench. The abutment wall of the tunnel was built to the upper end of the skewback for the tunnel arch. The retaining wall for the open cut was completed and the coping and railing set. The temporary tracks were then shifted to the north of the walls, and they remained in this position until travel was begun on the permanent tracks in the subway.

On account of the close proximity of the tracks to the trench for these walls, it was necessary to construct, for a considerable distance, a trestle supporting the south track. This work was done under a separate contract, No. 42, which was awarded to Messrs. E. D. Smith and Company on August 24th, 1897. On account of some necessary delay in starting on this contract, the contractors for the tunnel, at considerable expense to themselves, began the work of constructing the south wall of the tunnel before the temporary track was moved to the north. This wall was constructed in the same way as the north wall, except where it immediately adjoined the wall of the Baltimore and Ohio Tunnel near Twenty-fifth St., at which point the walls of the two tunnels were back to back. In order to avoid any possibility of an accident, the subway wall was built in sections of 50 ft. each,

the trench not being excavated in the alternate sections until the masonry on either side was well advanced. The back wall of the Baltimore and Ohio Tunnel was found to be in a very poor condition, and, as the subway wall was laid tight against it, each course was grouted in such a manner on the back that all the openings in the Baltimore and Ohio wall were filled. For this purpose, 322 batches of grout were used.

Steam shovels were then started at Thirtieth St., and a temporary incline was excavated to the west portal of the tunnel. The full section was then removed, approximately to the subgrade of the tracks, and centers were constructed for supporting the arch of the tunnel. These centers were designed by the contractors, and are shown in Fig. 1, Plate V. They were built 50 ft. in length, and so as to run on 12 wheels on tracks placed adjacent to the tunnel wall on either side, the weight of a section being about 510 tons. An opening 23 ft. wide was left through them to allow of the passage of trains removing the excavated material. The ribs were 6 ft. from center to center, and were lagged with 3-in. plank. The brick in the tunnel arch and the stone for the spandrel filling were generally brought in on construction tracks on the upper level. Seven sets of centers were built and used for the arch, the centers remaining in place 7 days after the arch was keyed. After some experience, it was customary to move a center forward in about 20 minutes after it had been lowered to the tracks. As soon as the brickwork for a section of arch was in place, the spandrel filling, of stone laid in Portland cement mortar, was built, and the top plastered with natural cement mortar, $\frac{3}{4}$ in. thick. After this plaster had set, the work of back-filling to the subgrade of the pavement on the avenue was begun.

This work was carried forward from west to east. The brickwork was begun on May 30th, 1898, and was completed with the setting of the keystone of the east portal on December 17th, 1898.

After the excavation for the tunnel was completed, the shovels were removed again to Thirteenth St., and the old retaining wall on the north side of the cut of the Baltimore and Ohio Railroad was removed, and the excavation, as far as the west portal of the tunnel, was completed to subgrade.

The west end of the Baltimore and Ohio Tunnel, for a distance of 250 ft. from the west end, is covered with a steel roof. Where the

back of the retaining wall supporting this roof, between the portals of the two tunnels, was exposed, it was faced with Leiperville stone and coped.

The work of placing the steel in the ventilation openings, of finishing around their tops, of placing the curb and paving the remodeled avenue, and of sodding and planting the trees and shrubs, followed in the order given. The final payment was made on June 5th, 1900. The completion of the work was delayed on account of some difficulty in fixing the paving grades at Fairmount Ave., caused by necessary conferences between the officials of the Union Traction Company and the Commissioners of Fairmount Park, which postponed the work of paving so late in the fall of 1899 that it could not be finished until the next spring.

Table No. 6 gives the average results of the tests of steel used. Four wooden Howe truss footway bridges cross the four tracks of the subway and the two tracks of the Baltimore and Ohio Railroad on the lines of Thirtieth, Twenty-ninth, Twenty-eighth and Twenty-seventh Sts.

TABLE No. 6.—AVERAGE PHYSICAL AND CHEMICAL TESTS OF STEEL. (Basic open hearth.) (Contract 33.)

	No. of tests.	Elastic limit.	Ultimate strength.	Elongation in 8 ins.	Reduction of area.	Carbon.	Phosphorus.	Manganese.	Sulphur.
Specification requirements..	..	0.54 Ult.	57 000 to 65 000	25.00	...	...	0.04	..	...
Ventilation openings.... ...	92	37 880	60 270	29.90	57.5	0.168	0.030	0.42	0.038

The tunnel before described is 2 710.42 ft. in length between portals. It is 52 ft. in width between the side walls, which are of heavy rubble masonry laid in Portland cement mortar, the face stone being a gneiss from Leiperville, Delaware County, Pa. For a distance of 45 ft. from the east portal the span is increased to 58 ft., so as to allow of the necessary side clearance to a turn-out leading to the railroad yard at Twentieth St.

The arch of the 52-ft. span is the segment of a circle of 43 ft. 8 ins.

FIG. 1.—FORTY-EIGHT INCH MAINS, AT TWENTY-FOURTH STREET.

FIG. 2.—FORTY-EIGHT INCH MAINS AT TWENTY-FOURTH STREET.

radius, with a rise of 8 ft. 8 ins., giving a clearance of 22 ft. over the rails at the center, with 18 ft. over the side tracks. It is composed of carefully selected, well burned, hard, red brick, laid in natural cement mortar, and is 2 ft. 10½ ins. thick at the center and 3 ft. 11¾ ins. at the skewback. The bonding is rather unusual, and is shown in Fig. 8. There are 7.25 cu. yds. of brickwork per linear foot of arch. The arch is not continuous, on account of the ventilation openings, of which there are thirteen. Twelve of these cut sections of 47 ft. 7 ins. in length out of the arch, and one of them occupies 78 ft. The construction of these openings has been described in detail. They are shown in Fig. 9.

The skewbacks are generally of Conshohocken stone of the dimensions shown in Fig. 8. Their cost is included in the price for the rubble masonry in the tunnel abutments above the neat line. These side-walls contain refuge bays, 5 ft. wide, 2 ft. 6 ins. deep, and 7 ft. high, arched with brick, and placed 50 ft. apart, alternately on either side of the tunnel. Upon the completion of the entire inside work of the tunnel, the masonry was thoroughly scraped, broomed and covered with Amphibolin waterproof whitewash.

All the water and gas mains and electrical conduits crossing the line of the tunnel were supported temporarily during the construction of the work. Nearly all of them were covered up in their original positions. The following exceptions occurred where there was not sufficient cover over the top of the brick arch to allow the mains to cross.

At Twenty-fourth St. two lines of 48-in. mains cross the line of the tunnel. On the line of Green St., and again at Fairmount Ave., single lines cross. At all these points the same method was used by Mr. Allen J. Fuller, then Engineer of Distribution, Bureau of Water, and now General Superintendent.

Special reducer pipes were manufactured. They are 37 ft. 7¼ ins. in length, horizontal on top and with the bottom 18 ins. higher at the center than at the ends. This makes a throat of 30 ins. diameter, the ratio between the throat and the main being as 1 to 2.51. The mains at Twenty-fourth St. are shown in Figs. 1 and 2, Plate VI. The results of Mr. Fuller's experiments on the difference in head due to the velocity in the throat, as measured with a mercury column, are given in Table No. 7.

TABLE No. 7.

Number of test.	Throat velocity, in feet per second.	Discharge in 24 hours, in millions of gallons.	Loss of head, in pounds.
1	4.504	14.3	0.018
2	6.777	21.5	0.044
3	10.111	32.0	0.100
4	11.287	35.7	0.133
5	13.450	43.6	0.182
6	14.358	45.5	0.184
7	14.767	46.8	0.213
8	16.381	51.9	0.283

Mr. Fuller, in commenting on these experiments, remarks:

"From the above given results it would appear that, in this case, the loss of head due to the reduced bore of the pipe is so slight that there can be little objection to the adoption of this method for crossing obstructions in the line of water or gas pipes or sewers. Care must be observed, however, in proportioning the throat or reduced area to the maximum required capacity of the conduit, otherwise the arrangement will prove unsatisfactory when discharging at a high velocity."

During the construction of the line at Twenty-fourth St., while the pipes were temporarily supported, a shifting engine and tender, on the temporary track adjacent, jumped the track, the tender falling 6 ft. and lodging upon the pair of pipes, which are about 14 ft. from center to center, and remaining there for about three hours, wholly supported by them. The accident did not break the pipes, nor cause any considerable leakage, although both mains were in service under a head of about 27 lbs. At the time of the accident the supports for the pipe in the excavation were as shown in Fig. 1, Plate VI, the tender falling from the tracks on the left side of the photograph where the west pipe was unsupported for nearly four lengths.

The drainage of the depressed tracks is effected by means of a conduit of concrete and brick placed in the center of the tracks. It is connected at three points with the deep sewer on Pennsylvania Ave. to the north of the north retaining wall, and was constructed in 1894 and 1895. Two of these points are west of the tunnel; the third is beneath the tunnel on the line of Twenty-fourth St. The detail of this conduit is the same as that described in the open subway.

Pennsylvania Ave., over the tunnel, was widened from 80 to 120 ft. from Hamilton St. to Green St., there being two sidewalks, each 14 ft. in width, and two driveways of 27 ft. each, between the main curb and the curb of the ventilation openings. Sodded grass

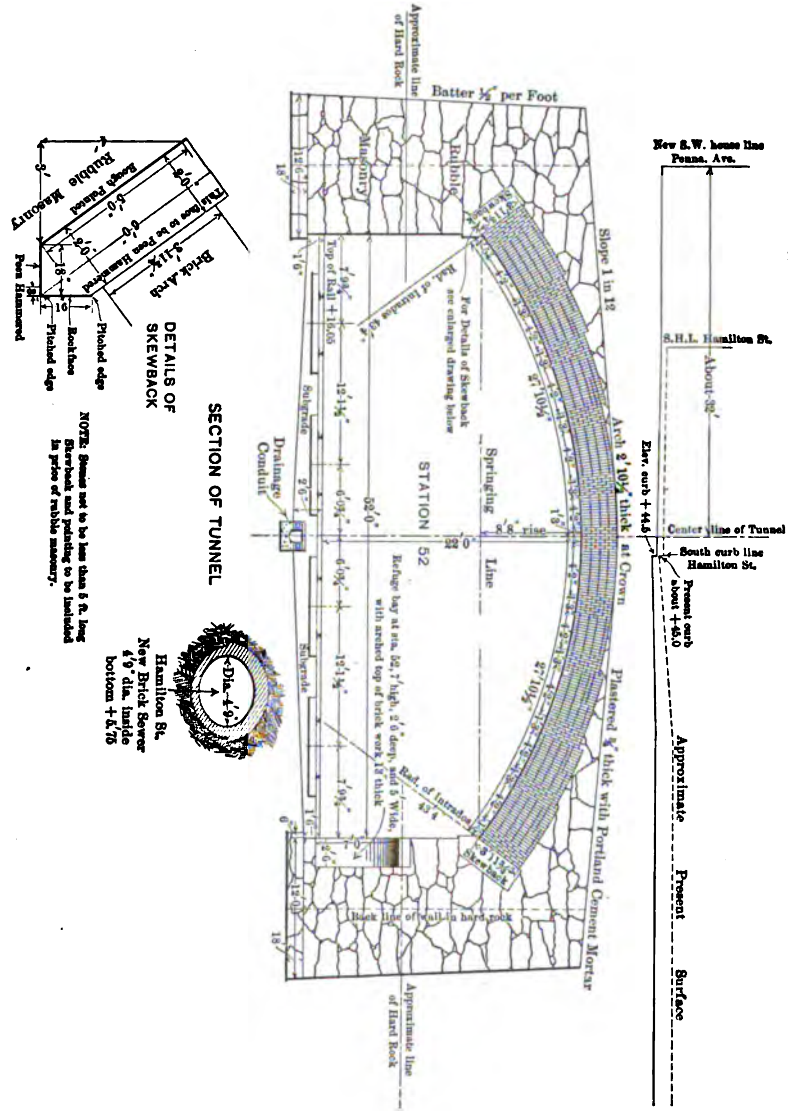

SECTION OF TUNNEL
STATION 52
DETAILS OF SKEWBACK
Approximate line of Hard Rock
Batter ½" per Foot
Rubble Masonry
Slope 1 in 12
Arch 2' 10½" thick at Crown
Springing Line
8' 8" rise
22' 0"
Plastered ¼" thick with Portland Cement Mortar
Back line of wall in hard rock
Drainage Conduit
Subgrade
Top of Rail + 15.05
For Details of Skewback see enlarged drawing below
Refuge bay at sta. 52, 7' high, 2' 6" deep, and 5' wide, with arched top of brick work 13" thick
Hamilton St. New Brick Sewer 4' 9" dia. inside bottom + 5.75
New S.W. house line Penna. Ave.
S.H.L. Hamilton St.
About 32'
Elev. curb + 44.5
Center line of Tunnel
South curb line Hamilton St.
Present curb about + 45.0
Approximate Present Surface
Brick Arch
Rubble Masonry
Rough Pointed
Pean Hammered
Pitched edge
Rockface
NOTE: Stones not to be less than 5 ft. long. Skewback and pointing to be included in price of rubble masonry.

FIG. 8.

plats, 6 ft. in width, are placed next to the main curbs, and are planted with Asiatic Buttonwood (*Platinus Orientalis*). The spaces around the ventilation openings are sodded and planted with shrubs specially selected to live under the conditions which exist. *Ampelopsis* vines are planted against the walls. The sidewalks are paved with brick, and the driveways with Trinidad Lake asphalt upon a cement concrete base, 8 ins. in thickness, the asphalt wearing surface, 2 ins. in thickness, being placed upon a 1-in. binder coat placed upon the cement concrete. All the curbing is of granite, 8 ins. in width and 24 ins. deep.

Table No. 8 gives the prices of the principal items which were used on this work. It should be noted that the excavation was measured without classification, and included all back-filling of retaining walls and abutments, over the tunnel and at other places, as directed. It also included the removal of all old walls and sewers; the maintenance of all travel; of water pipes, gas pipes, and electric conduits, and all sheeting and shoring where required.

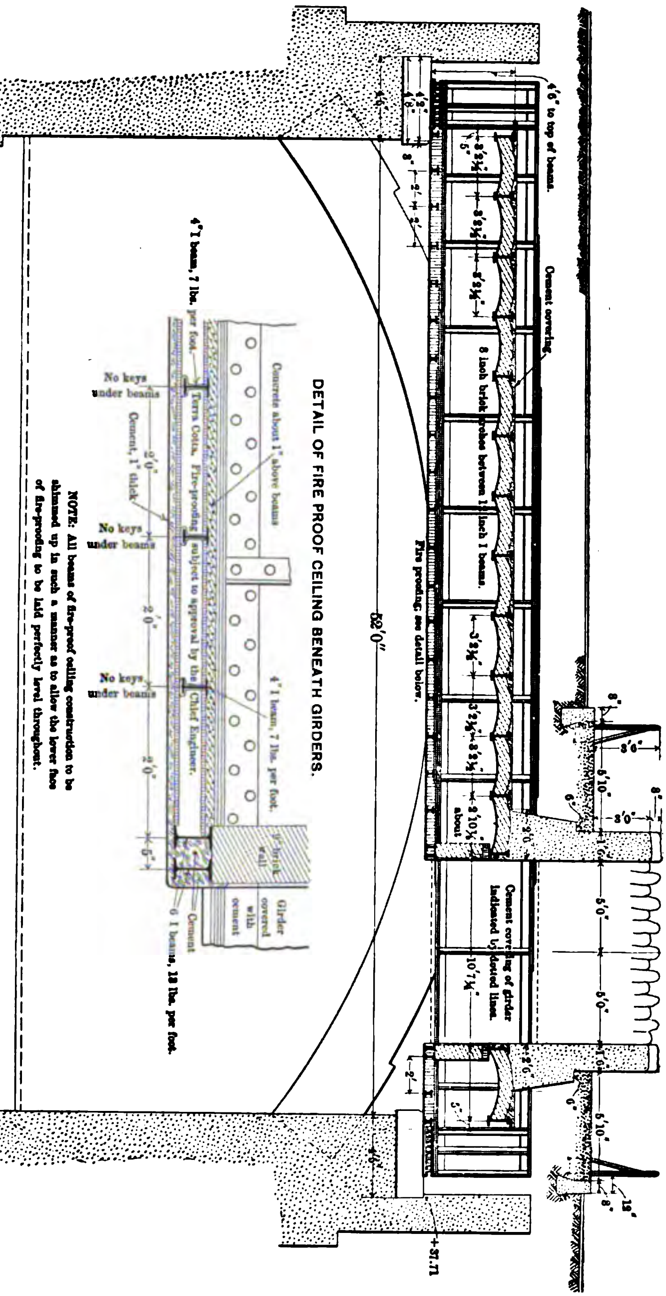
TABLE No. 8.—Prices. Tunnel and Subway. Contract 33.

Item.	Price.
Excavation	$0.65 per cubic yard.
Rubble masonry, below neat line	5.00 " "
Rubble masonry, in retaining walls, above neat line	5.75 " "
Rubble masonry in tunnel abutments, above neat line, including skewbacks of tunnel arch	6.40 " "
Cut stone voussoirs in tunnel portals	18.00 " "
Granite bridge-seats, ventilation openings	33.00 " "
Brick masonry in tunnel arch	7.875 " "
Coping for retaining walls	1.50 per linear foot.
Asphalt paving, 8-in. concrete base	2.86 per square yard.
Brick sidewalk paving	0.90 " "
8-in. straight granite curb	1.40 per linear foot.
8-in. curved granite curb	1.60 " "
15-in. drainage conduit, in rock	2.00 " "
15-in. " " in earth	1.90 " "
12-in. " " in rock	1.90 " "
Grass sodding	0.60 per square yard.
Terra cotta covering, in ventilation openings, including cement, concrete, and plaster	0.44 " " foot.
Steel in ventilation openings	0.025 per pound.

The total cost of the work under this contract was $1 014 992.97.

Temporary Trestle on North Side of Tunnel.

During the construction of the tunnel it became necessary to support the temporary tracks on the north side of the avenue by means of a temporary trestle. The work was placed under contract with E. D. Smith and Company (Contract 42), and was completed by them



TRANSVERSE SECTION OF VENTILATION OPENINGS.

FIG. 9.

during the tunnel construction. The work was done by unit prices, the principal ones being as follows:

Lumber in trestle, framed and erected....................	\$42.00 per thousand feet, B. M.
Laying track on trestle, using old rails from the work and new sawed ties.............	1.70 per linear foot.

The total amount paid under this contract was \$19 049.18.

Character and Quality of Stone.

The Contractors elected to use the following grades of stone for retaining walls and abutments, and the same were approved.

Leiperville Stone.—A light-colored gneiss from Chester, Delaware Co., Pa. It was used on the walls between Thirteenth and Fifteenth Sts., except on the north side between Broad and Fifteenth Sts.; also, on both sides between Nineteenth and Twentieth Sts., and on the abutment walls of the tunnel.

Rittenhouse Stone.—A dark-colored gneiss from Germantown, Philadelphia. Used on the north wall between Broad and Fifteenth Sts., and on the north abutment of the Fifteenth St. Bridge.

French Creek Granite.—A very dark, close-grained, heavy syenite from the Falls of French Creek, Chester Co., Pa. Used on the walls and abutments between Fifteenth and Nineteenth Sts., and on the north wall between Twenty-first St. and the tunnel portal.

Conshohocken Stone.—A medium-colored, hard, mica schist, from Conshohocken, Montgomery Co., Pa. Used on the south wall between Twenty-first St. and the tunnel; on the north retaining wall from the west end of the tunnel to Thirtieth St., and for the skewbacks in the tunnel.

Clearfield County Stone.—A medium-colored, hard, sandstone from Curwensville, Clearfield Co., Pa. Used on the abutments of the bridge at Broad St. and the south abutment at Fifteenth St., both abutments at Twentieth St., and generally for copings throughout the work.

Lumberville Stone.—A light-colored quartzite, of granitic nature, from Lumberville, Bucks Co., Pa. Used on the north and south walls, between Twentieth and Twenty-first Sts.

The physical qualities and other properties of the above-mentioned stone are given in Table No. 9.

TABLE No. 9.—Record of Tests of Stone Used in the Construction of the Pennsylvania Avenue Subway.*

Mark.	Name of stone and location of quarry.	Dimensions of specimen.	Weight per cubic foot.	Absorption, percentage of.	Specific gravity.	Compressive Strength, in Pounds.		How Tested.		Average Compressive Strength, in Pounds per Square Inch.		Remarks.
						Ultimate.	Per square inch.	Bed or edge.	Grain.	On bed.	On edge.	
A1.....	French Creek.	$8 \times 8 \times 7\frac{7}{8}$	188.52	1.00	3.08	1 177 855	18 404	on bed.	none.	17 274	7 910	
A2.....		$8 \times 8 \times 7\frac{7}{8}$	188.20	1.00	3.07	1 032 640	16 144	"	"			
A3.....		$7\frac{15}{16} \times 8 \times 7\frac{7}{8}$	188.95	1.00	3.06	484 050	7 623	on edge.	"			Crushed on one side.
A4.....		$7\frac{15}{16} \times 7\frac{15}{16} \times 7\frac{15}{16}$	189.69	1.00	3.05	516 880	8 196	"	"			
B1.....	Lumberville.	$8 \times 8 \times 7\frac{7}{8}$	158.38	0.99	2.62	571 179	8 925	"	against.	14 841	8 637	
B2.....		$8 \times 8 \times 8$	158.51	0.97	2.64	1 032 640	16 135	on bed.	with.			Socket of compression tool broke; 629 265 lbs. replaced.
B3.....		$8 \times 8 \times 8$	158.14	1.02	2.63	935 880	14 623	"	"			
B4.....		$7\frac{7}{8} \times 8 \times 8$	158.58	0.88	2.63	536 001	8 349	on edge.	against.			
B5.....		$8 \times 8 \times 8$	157.40	1.08	2.63	880 971	13 765	on bed.	with.			
C1.....	Rittenhouse.	$8 \times 8\frac{1}{16} \times 7\frac{7}{8}$	176.05	0.15	2.84	1 174 688	18 211	on edge.	against.	11 636	13 984	
C2.....		$8 \times 8 \times 7\frac{3}{4}$	174.98	0.15	2.88	871 290	13 614	on bed.	with.			
C3.....		$8\frac{1}{16} \times 8 \times 7\frac{13}{16}$	176.16	0.12	2.84	629 265	9 756	on edge.	against.			
C4.....		$7\frac{7}{8} \times 8\frac{1}{16} \times 7\frac{3}{4}$	176.18	0.18	2.84	613 180	9 657	on bed.	with.			
D1.....	Curwensville.	$8 \times 8 \times 8$	143.11	2.61	2.44	542 186	8 471	"	"	7 513	4 463	
D2.....		$8 \times 8 \times 8$	142.28	2.54	2.44	248 479	3 882	on edge.	against.			
D3.....		$8 \times 8 \times 8$	146.31	1.75	2.37	322 700	5 042	"	"			
D4.....		$8 \times 8 \times 8$	145.33	2.04	2.39	325 927	5 093	on bed.	with.			
D5.....		$8 \times 8 \times 8$	145.18	2.58	2.43	574 406	8 975	"	"			
E1.....	Leiperville.	$8\frac{1}{16} \times 8 \times 7\frac{13}{16}$	165.84	0.19	2.69	564 725	8 755	"	against.	6 496	9 505	
E2.....		$7\frac{15}{16} \times 7\frac{7}{8} \times 7\frac{3}{4}$	164.58	0.21	2.68	408 375	6 447	on edge.	with.			
E3.....		$7\frac{15}{16} \times 7\frac{13}{16} \times 7\frac{13}{16}$	165.00	0.21	2.69	635 719	10 254	on bed.	against.			
E4.....		$8\frac{1}{16} \times 8 \times 7\frac{3}{4}$	164.90	0.20	2.68	418 056	6 404	on edge.	with.			
F1.....	Conshohocken.	$8\frac{1}{16} \times 8 \times 8$	....	....	....	522 774	8 105	"	against.	10 417	7 532	
F2.....		$7\frac{15}{16} \times 8\frac{1}{16} \times 8$	....	....	....	445 326	6 958	"	"			
F3.....		$8 \times 8 \times 7\frac{15}{16}$	....	....	....	580 860	9 076	on bed.	with.			
F4.....		$8\frac{1}{16} \times 8\frac{1}{16} \times 8$	....	....	....	509 866	7 844	"	"			
F5.....		$7\frac{15}{16} \times 8 \times 8\frac{1}{16}$	....	....	....	910 014	14 331	"	"			

* Crushing Tests made at Phœnixville, Pa.

Excavation of the Core. The Bridges.

Upon the completion of the retaining walls and bridge abutments upon the north and south sides of the subway, all railroad travel was diverted to Hamilton St. (except the connection with the grain elevator and Bement, Miles and Company, on the south side at Twentieth St., which was maintained over the construction tracks used by the contractors), and the avenue was given over in sections to the work of removing the core, building the bridge piers between the main walls, and constructing the bridges. This work was embraced in Contract 14, which extended from the west side of Thirteenth St. to the east portal of the tunnel. The work covered the completion of the bridge abutments, the low ends of the inside walls of the several inclines, the bridge piers, the construction of the bridges (except railings), the grading and paving of their approaches, the railings on the retaining walls not completed on other contracts, paving all adjacent driveways and sidewalks, the construction of the drainage ducts in the subway, and the preparation of the subgrade for the permanent tracks.

All the work was done at unit prices, except that a lump sum was bid for all the bridges from Broad to Twenty-first Sts., inclusive, and including, also, the paving of the decks and the approaches.

The bridges at Sixteenth, Seventeenth, Eighteenth, Nineteenth and Twentieth Sts. were erected upon the core as false-work, the intermediate piers usually being constructed in pits. Travel was maintained in all cases. At Twenty-first St., travel was cut off, and the piers were built and the bridge erected after the excavation was made. At Fifteenth St., travel was maintained by means of temporary Howe trusses; then the excavation was made, the piers were built and the bridge erected. At Broad St., half the street was closed to travel at a time; then the excavation was made, half the masonry was built and half the bridge erected and paved.

The excavated material, which was paid for by the cubic yard, without classification, including the cost of maintaining travel, was taken through the subway to the west, and, until the completion of the tunnel, was run up an incline at the east end of the tunnel and taken out over the temporary tracks. The contractor had an arrangement with the railroad company by which he loaded cars furnished by the company, and delivered them at some point agreed upon on the

temporary tracks, and unloaded them after the railroad company had hauled them to the dump.

The greater part of the excavation was taken out by means of steam shovels, of which the contractor usually had three at work. About 500 000 cu. yds. were used by the railroad company to fill the approaches to the Delaware River Bridge at Yardley, on the New York Division. The next largest amount was used at Woodlane, on the Reading Division, a point on the Schuylkill River, below Conshohocken, Pa., where it was used to make a railroad yard. A considerable quantity of the rock was deposited on the Atlantic City Division, on the meadows between Pleasantville and Atlantic City, N. J., and the remainder was delivered at scattered points.

The highway bridges over the subway are all of the plate-girder, deck type, with solid steel floors carrying improved paving. The clearance over the main railroad tracks was 20 ft.: over the side tracks, 15 ft. Over the main tracks at the north end of the Broad St. Bridge a special clearance of 18 ft. was agreed upon, so as to prevent an undue change of the street grade. Even with these low clearances it was necessary to change the elevation of Broad St. by 4.5 ft.; of Fifteenth St., by 5.1. ft., and of Eighteenth St., by 2.2 ft.

In all cases the metal curb of the bridge is a continuation of the stone curb of the approaches, and the railings are upon the building lines, thus making the entire bridge structure below the plane of the intersecting street.

Except upon the bridge at Fifteenth St., where there is a grade of 3.96%, and where the paving is vitrified brick, the roadways are paved with sheet asphalt, and, in all cases, the sidewalks are granolithic. In all bridges, expansion is provided for by means of a specially designed joint.

The bridges at Fifteenth, Sixteenth, Seventeenth, Eighteenth, Nineteenth and Twentieth Sts. carry trolley tracks. The rail is a 6-in., 71-lb. section, laid upon longitudinal wooden stringers placed in the troughs of the Z-bar floor, for the purposes of insulation. The rail joints are "cast welded." In addition to the cast weld a ¾-in. return copper cable is placed between the rails and connected with them every 10 ft. to assist in making perfect insulation.

Upon the steel deck of the driveway was placed bituminous concrete to a depth to cover the rivet heads on the upper part of the

Z-floor section, in the gutters, and following the crowning of the street. The asphalt wearing surface consisted of a binder coat, 1 in. in thickness, covered by the wearing surface proper, 2 ins. thick. The troughs of the sidewalks were filled with Portland cement concrete finished with a granolithic wearing surface. Inlets were placed above all expansion joints, and connected with the sewers beyond the abutments.

The loads used in the design of all bridges on the lines of intersecting streets consisted of the following:

1st. The dead load.

2d. A uniform live load of 100 lbs. per square foot.

3d. The driveways were tested with a concentrated load as follows:

A load of 40 tons equally distributed on 4 wheels of 6 ft. gauge, spaced 20 ft. between axles.

4th. All sidewalk details were proportioned for a local loading of 110 lbs. per square foot.

All railroad bridges were designed under the standard specifications of the Philadelphia and Reading Railroad Company.

Complete detailed (not shop) drawings were prepared for all the highway bridge work, while nothing but the general lines of the railroad bridges was given for the purpose of bidding. Fig. 10 shows a typical drawing of three sections of a highway bridge.

Generally, the sidewalks were carried upon overhanging cantilever brackets, mainly on account of the additional headroom offered where crossing an inclined track leading to some industrial establishment. At Twentieth, Sixteenth and Broad Sts., a line of girders carried the outside of the sidewalk and the railing.

All steel was specified to be made by the "open hearth" process. When made in an "acid furnace," the phosphorus was required not to exceed 0.07%; if made in a "basic furnace" the limit was 0.04 per cent. The metal was required to show on a standard test piece the following results: Tensile strength, 57 000 to 65 000 lbs. per square inch; elongation in 8 ins., 25%; elastic limit, 54% of the tensile strength. For plates over 16 ins. wide, the elongation was to be 22%, and for plates over 42 ins. wide, 20 per cent. Hot and cold-bending, and quenching tests were required.

As to painting, all steel, before leaving the rolling mill, and before being exposed to the weather, was required to be thoroughly cleaned from all loose black scale, and given one coat of pure raw linseed oil. Before leaving the shop it was again required to be thoroughly cleaned and a heavy coat of red lead paint was applied. Two additional coats of red lead tinted with lampblack to make a dark chocolate color were applied after erection, the inaccessible parts after erection being painted previously.

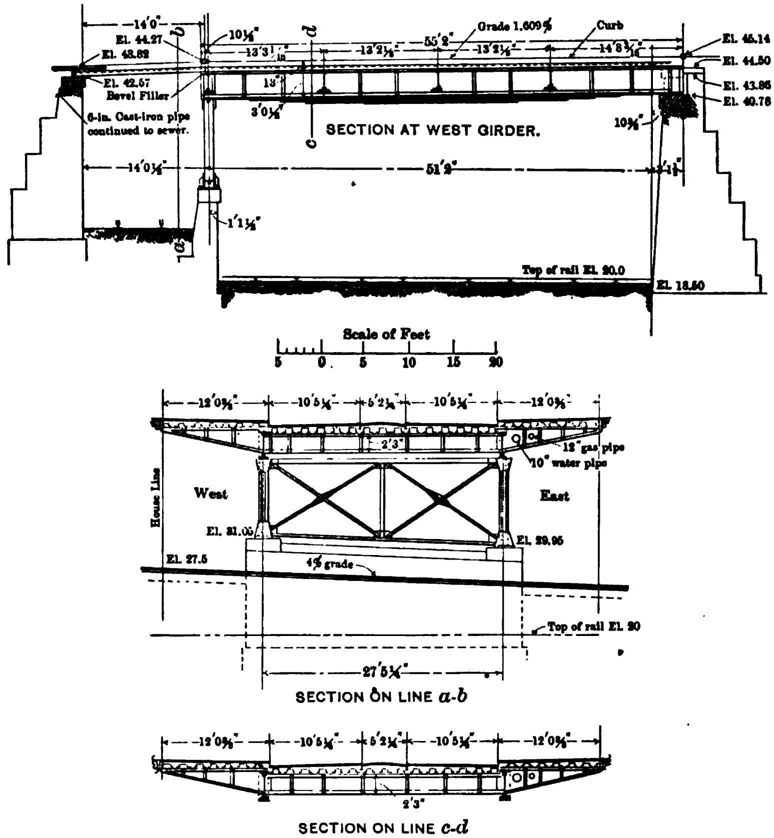


Fig. 10.

Tables Nos. 10 and 11 give the results of the tests made upon the metal in the bridges on this contract as well as the weights of each structure and the weights per square foot of the metal-work. It will be noticed that, in the tables of the tests, averages of all the tests and analyses are given.

TABLE No. 10.—AVERAGE PHYSICAL AND CHEMICAL TESTS OF STEEL. (BASIC OPEN HEARTH.) CONTRACT 14.

Location of bridge.	No. of tests.	Elastic limit.	Ultimate strength.	Elongation in 8 ins.	Reduction of area.	Carbon.	Phosphorus.	Manganese.	Sulphur.
Specification requirements.	...	0.54 ult.	57 000 to 65 000	25.00	......	......	0.04	....	......
Broad St.	136	36 310	60 720	29.28	56.58	0.17	0.027	0.43	0.041
Fifteenth St.	95	35 980	60 920	29.55	56.60	0.17	0.032	0.42	0.042
Driveway west of 15th St.	17	36 470	60 490	30.86	57.30	0.16	0.023	0.44	0.036
Sixteenth St.	42	37 290	60 330	29.85	56.80	0.16	0.028	0.43	0.040
Seventeenth St.	40	35 790	61 390	29.33	58.59	0.18	0.026	0.41	0.040
Eighteenth St.	37	36 440	63 550	29.54	57.90	0.17	0.032	0.43	0.044
Driveway west of 18th St.	23	37 510	60 150	29.11	58.00	0.15	0.028	0.42	0.041
Nineteenth St.	27	35 900	61 170	29.97	58.70	0.16	0.033	0.41	0.040
Twentieth St.	31	35 560	61 180	29.60	57.50	0.17	0.032	0.41	0.040
Twenty-first St.	67	34 860	60 380	31.40	55.30	0.16	0.027	0.45	0.037
Averages.	515	36 210	61 020	29.84	56.80	0.165	0.029	0.42	0.040

The following standards were required for linseed oil, red lead and lampblack:

"Raw linseed oil must be well settled and strictly pure, and free from resinous and mineral oils and gums.

"Red lead in oil must be of a good, bright color and finely ground. The pigment must contain at least 95% of red oxide of lead; no sample will be accepted that contains more than 2% of foreign matter that is vitrified, or that contains metallic lead; or that, when mixed with linseed oil and drying Japan without grinding, and applied in a good body to a vertical surface of iron, will not dry without running or separating.

"Lampblack in oil must be finely ground to a stiff paste. No sample will be accepted which is not equal in color to, or has a less staining power than, calcined lampblack, or that contains empyreumatic matter, or carbon black."

Drainage conduits, shown in Fig. 11, were placed generally in the center of the subway, the cross-section of the subgrade being arranged so as to throw all the water to them. They consist of an invert of concrete, semi-circular in cross-section, with diameters of 12 or 15 ins., as required, and placed upon a sufficient grade to carry off all the water falling upon the subway, or from adjacent buildings, to a silt basin adjacent to the deep sewers on the intersecting streets. The top of the conduit is covered with flagstones placed on top of brick

TABLE No. 11.—TABULATED DATA AS TO HIGHWAY BRIDGES (CONTRACT 14).

Location.	Number of spans.	Length of spans.	Total length.	Width of driveway.	Width of sidewalks.	Total width.	Area of steel-work, in square feet.	Total weight of steel, in pounds.	Weight of steel, in pounds per square foot.
Broad St............	5	38 ft. 7 15/16 ins. 61 " 2 " 61 " 2 " 61 " 2 " 33 " 3 "	255 ft. 4 15/16 ins.	69 ft. 2¼ ins.	2 at 22 ft. 0½ ins.	113 ft. 3¼ ins.	29 772	2 265 062	76.4
Fifteenth St........	6	40 " 0 " 13 " 10½ " 33 " 0 " 67 " 11½ " 67 " 11½ " 14 " 3 "	237 " 0 "	26 " 0¾ "	2 " 12 " 0⅜ "	50 " 1½ "	12 125	817 825	67.4
Sixteenth St........	2	14 " 11 " 33 " 11 "	57 " 10 "	26 " 0¾ "	1 " 12 " 0⅜ "	50 " 10½ "	2 942	217 097	73.8
Seventeenth St......	3	14 " 3 " 53 " 1 1/16 " 9 " 8 "	77 " 0 "	26 " 0¾ "	2 " 12 " 0⅜ "	50 " 1½ "	3 743	253 410	67.8
Eighteenth St.......	3	13 " 10½ " 14 " 2 " 52 " 2 "	80 " 2¼ "	26 " 0¾ "	2 " 12 " 0⅜ "	50 " 1½ "	4 084	258 875	64.1
Nineteenth St.......	2	14 " 0½ " 51 " 2 "	70 " 2 "	26 " 0¾ "	2 " 12 " 0⅜ "	50 " 1½ "	3 516	220 987	62.8
Twentieth St........	1	54 " 7½ "	54 " 7½ "	26 " 0¾ "	2 " 12 " 0⅜ "	50 " 1½ "	2 995	201 575	67.3
Twenty-first St......	4	15 " 0 " 77 " 1⅝ " 55 " 5½ " 42 " 5⅝ "	190 " 4 "	26 " 0¾ "	2 " 12 " 0⅜ "	50 " 1½ "	9 539	659 239	69.1

side-walls laid with open joints, the top of the flag being designed so as to be from 12 to 24 ins. below the top of the rail. Manholes with cast-iron frames and covers are placed every 100 ft., to afford means of cleaning. The depth of the brickwork is constant, stopping at sub-grade; the variable depth, required on account of the grade of the conduit, being made in the concrete work. These drains have proved to

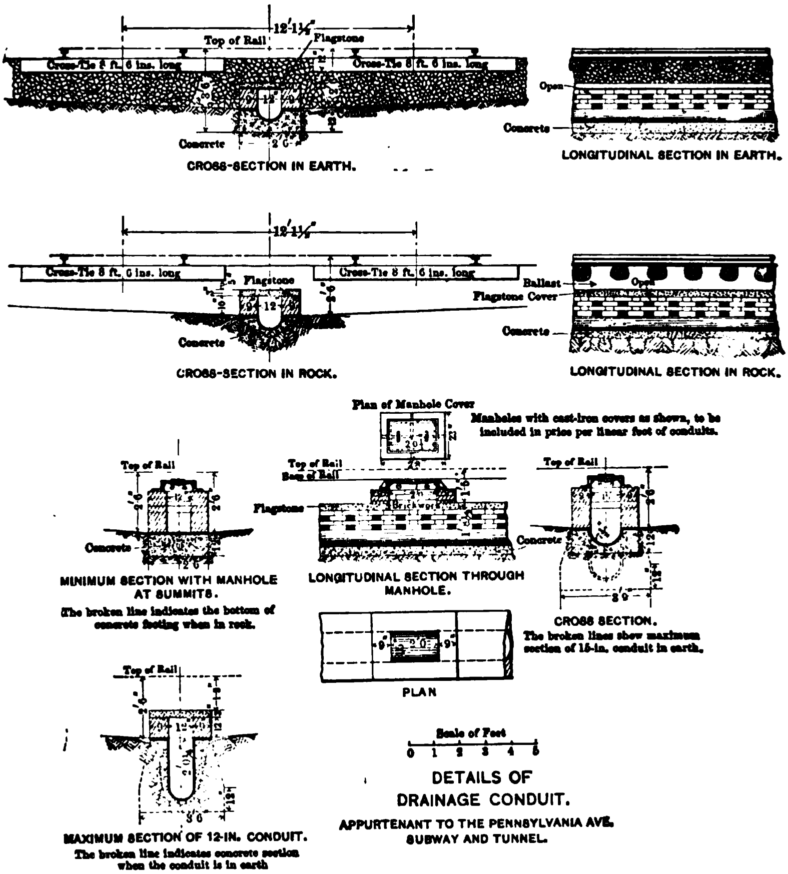


FIG. 11.

be very effective. They were paid for at a price per linear foot for each diameter, including manholes and appurtenances. As the grades were shown on the contract drawings, there was no uncertainty as to bidding.

The principal cost of the several more important items is shown in able No. 12.

TABLE No. 12.

Excavation	$0.59 per cubic yard.
Rubble masonry, above neat line	5.75 " " "
Ashlar masonry, in piers	15.00 " " "
Rubble masonry, below neat line	5.00 " " "
Coping, 10 x 30 ins	1.25 per linear foot.
Bridges	298 000.00 lump sum.
Additional steel-work	0.0825 per pound.
Railing No. 4	1.60 per linear foot.
Railing No. 6	0.95 " " "
Railing for Broad St. Bridge	22.00 " " "
Granite block paving, sand base	2.60 per square yard.
12-in. drainage conduit, in earth	1.80 per linear foot.
12-in. drainage conduit, in rock	1.90 " " "
15-in. drainage conduit, in earth	1.90 " " "
15-in. drainage conduit, in rock	2.00 " " "

The total amount paid under this contract was $736 038.92. The contractors were Messrs. E. D. Smith and Company, for whom Mr. George Rice was Engineer. Work was begun on April 15th, 1897, and was finished on August 21st, 1899. The length of time consumed does not by any means represent the time occupied in actual construction. On account of the nature of the work, it was necessary to begin on different portions of it as the other contracts were completed.

The excavation of the material between Twentieth St. and the east portal of the tunnel occupied practically 13 months. Nearly all this material was rock which was rather difficult to remove.

Bridge Railings.

The ornamental railing for the bridge at Broad St. was included in the contract for the bridges. A contract was entered into with the North Penn Iron Company (Contract 46) to manufacture and place upon all the other bridges cast-iron railings and newels.

The work was done at unit prices, which were as follows:

Cast-iron railing, in place	$2.73 per linear foot.
Cast-iron newels	7.80 each.
Bronze name-plates	19.50 "

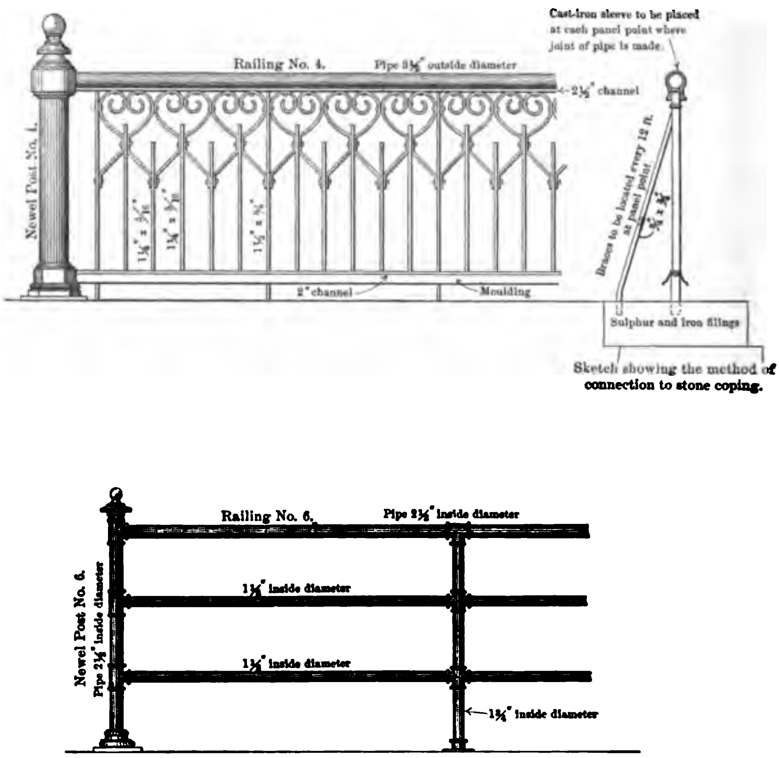
The total amount paid on this contract was $4 941.51.

Railings.

On the contracts for the construction of retaining walls, prices were generally asked for railings Nos. 4 and 6, as shown on Fig. 12. Where the face of the wall was on the building line the gas-pipe railing, No. 6, was used throughout. Where a driveway or footwalk adjoined the wall, No. 4 was used.

Protecting Bridges.

In 1894, when the abolishment of grade crossings on Pennsylvania Ave. was first seriously considered, the City and the railway company jointly rebuilt a bridge on the line of Girard Ave. over Pennsylvania Ave., to the west of the subway work, with a clearance of only 17.5 ft.



DESIGNS OF RAILINGS FOR PENNSYLVANIA AVE. SUBWAY AND TUNNEL.

Fig. 12.

over the tracks. It was decided to encase the entire metal-work on the underside of the bridge with tongued and grooved white pine boards, and to paint them with asbestos paint.

Five years after the bridge had been erected, an examination of the metal-work was made, which showed that the original paint was prac-

tically intact, and that the paint on the outside of the wood sheathing immediately over the main tracks was still in place and the wood in good condition.

In view of this experience, and upon the completion of the bridgework in the subway, it was decided to thoroughly clean all the metalwork, give all the bridges that crossed streets two coats of white lead body paint and to give all bridges over the subway a coat of red oxide of iron paint, and then encase all the last-named bridges with single-faced, tongued and grooved white pine fencing, in widths not to exceed 4 ins. After the completion of the woodwork, the protective casing was painted with two coats of asbestos paint, and three months thereafter two more coats were applied.

A contract for this work was made with Ryan and Kelley (Contract 57), which also included a final coat of paint on all the railings, both on the bridges and retaining walls; the protection of the water pipes which were suspended from the bridges, and a number of items of general cleaning up. (See Figs. 13 and 14.)

The water pipes on straight sections were cased as follows:

1st. One layer of No. 2 asbestos roofing and insulating felt.

2d. One layer of 1-in. hair felt.

3d. One layer of No. 2 asbestos roofing and insulating felt.

4th. One layer of 1-in. hair felt. Each layer to be wrapped with tenfold sail twine.

5th. One layer of resin-sized sheathing.

6th. One layer of three-ply "A" asbestos roofing, secured with No. 17 galvanized-iron wire.

To cover the bells and lapping over the straight sections, the following was done:

7th. One layer of No. 2 asbestos roofing and insulating felt.

8th. One layer of 1-in. hair felt.

9th. One layer of resin-sized sheathing.

10th. One layer of canvas with the ends drawn to make a snug fit against the asbestos roofing on the straight sections of the pipe; outside of the canvas to be painted with waterproof composition.

Three 6-in., one 10-in., and one 20-in. pipe were thus covered; the price bid per linear foot being irrespective of the diameter. The

work on this contract was done under unit prices, of which the following are the most interesting:

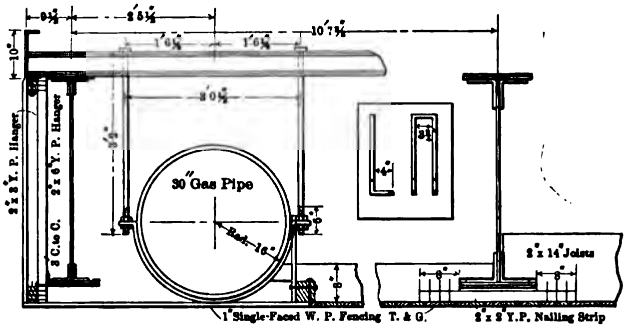
Painting of bridges	$4 100.00	
Protection of bridges, except the last two coats of paint	89.00	per thousand feet, B. M.
Last two coats of paint	1 790.00	
Painting bridge railings, one coat	0.12	per linear foot.
Painting No. 4 railings	0.09	" " "
Painting No. 6 railings	0.06	" " "
Covering water pipes on bridges	1.50	" " "

The total cost of the work done was $27 517.95.

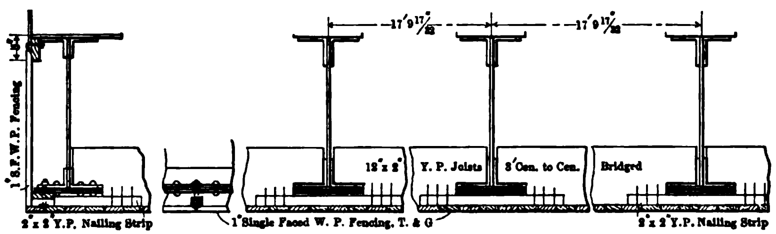
Work on, and East of, Thirteenth Street.

The entire work of altering the grades of Thirteenth, Callowhill, Hamilton, Buttonwood and Twelfth Sts., together with the elevated portion of the railroad over and east of Thirteenth St. (except laying the permanent tracks), was included in Contract 12, which was awarded to Messrs. P. H. Flynn and Company on July 28th, 1896. All the work on this contract was paid for by unit prices, except the steel work of the bridges, which was bid for in a lump sum.

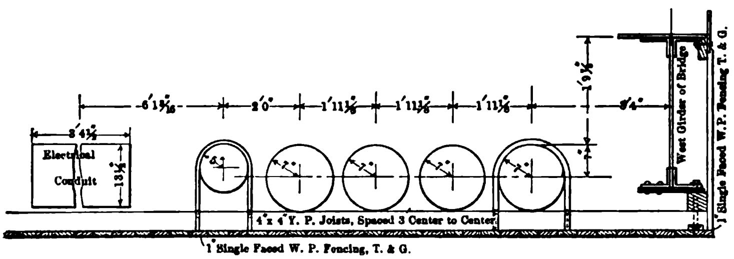
Before work was begun the double-track railroad approach to the Reading Terminal at Twelfth and Market Sts. was carried on a wrought-iron viaduct from Callowhill St. east of Twelfth to Thirteenth and Noble Sts., and thence by a masonry approach to the grade of the old street at Broad and Noble Sts. The alignment of this part of the structure was not changed. The wrought-iron viaduct between Callowhill and Twelfth Sts. was lowered about 2 ft. at Twelfth St., and remained unchanged at Callowhill St., the grade of Twelfth St. being lowered by the same amount. The metal-work of the viaduct was blocked up, the masonry cut down, and new bearing plates were inserted, to suit the new grade. Twelfth St. is crossed by a plate-girder, half-through span, which is skewed at an angle of 66° 17′ with the street, and consists of two girders 28.5 ft. from center to center, supporting the ends of a trough-floor composed of plates and angles, the troughs being 20 ins. deep. The ballast and ties are placed in the troughs so that the distance from the top of the rail to the clearance line of the street below is a minimum.



Sixteenth Street Highway and Railroad Bridge



SIDE VIEW



Sheathing: Broad Street Bridge

NOTE: At columns and newel post of railing, the 2 x 5-in. Y. P. Stringer bolted to base of railing, as shown, is to follow around the edge of base of columns and newel posts of railing. The 2" x 2-in. Y.P. nailing strips at bottom of Girder to extend far enough beyond the Y. P. stringer to allow the sheathing to be boxed around column and newel posts and brought down square with base of same to catch sheathing on bottom of Bridge.

BRIDGE PROTECTION

PENNSYLVANIA AVE. SUBWAY.

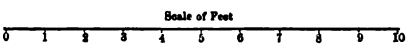


FIG. 13.

Between Twelfth and Thirteenth Sts. the old metal structure was entirely removed, and was replaced by retaining walls of rubble masonry with earth filling between.

Between Twelfth and Thirteenth Sts., on the south side of the tracks, is located a coal yard, the property of the Philadelphia and Reading Railway Company. This was excavated to an average depth of 10 ft. and connected with the Terminal tracks west of Thirteenth St. by means of two sidings. At Thirteenth St. the two railroad tracks which are on Noble St., and extend to the Delaware River, connect with the Terminal tracks. The bridge at Thirteenth St. has provision for a highway passageway on the north, on the line of Noble St. and six railroad tracks to the south. It is a steel, half-through, plate-girder bridge which has a solid steel floor and is very badly skewed. The steel floor rests upon the bottom chord of the plate girders. The drainage is effected with bituminous concrete, placed in the bottom of the troughs and sloped toward the center, where a hole is provided to allow the water to pass through and into a half-round gutter of skelp-iron, leading to a vertical pipe fastened to the abutment, and thence into the sewer. Ballast is placed directly over this bituminous concrete. The highway portion of the bridge is of a solid-steel trough section in the floor, covered with bituminous concrete and paved with granite blocks. The total weight of the steel in this bridge is 610 754 lbs.

The grade of Thirteenth St. at the intersection of Noble St. is lowered 13.6 ft., and this is the deepest point in the depression. From this point the new grade ascends to the north at the rate of 3.7%, reaching the grade of the old street at Nectarine St., a distance of 4.71 ft. On the south, the ascending grade is at the rate of 3.5%, reaching the original grade of the street at Carlton St., a distance of 388 ft. On the west side, just south of Noble St., is the depressed freight yard of the subway, the main driveway of which meets the level of Thirteenth St., and thus makes an access to the depressed yard.

To the north of Noble St. there are a number of large buildings; on the south the number is smaller. Before any steps were taken to change the grade of the street, the foundations of all structures on Thirteenth, Callowhill, and Hamilton Sts. were underpinned and carried down below the new grade of the street, generally to a depth of 3 ft. below the new pavement subgrade. On account of the impracti-

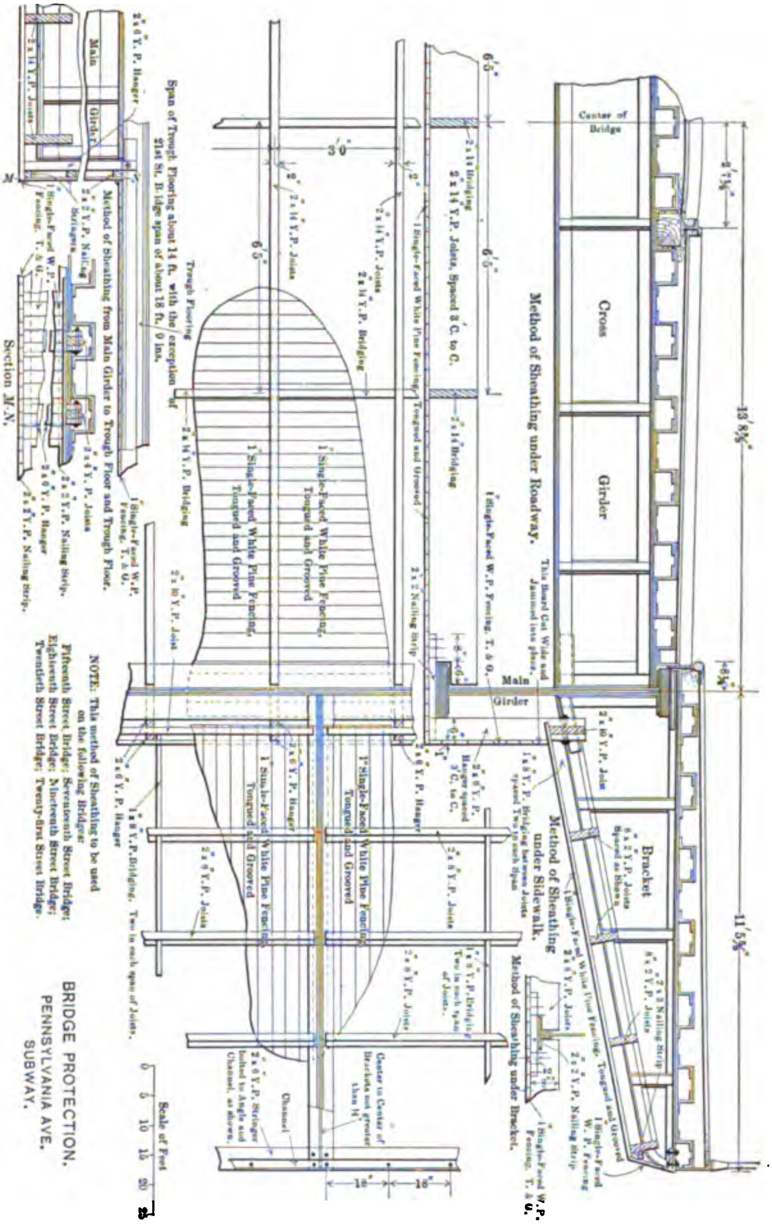

BRIDGE PROTECTION,
PENNSYLVANIA AVE.
SUBWAY.
Method of Sheathing under Roadway.
Method of Sheathing under Sidewalk.
Method of Sheathing under Bracket.
Method of Sheathing from Main Girder to Trough Floor and Trough Floor.
Section M-N.
Center of Bridge
Cross Girder
Main Girder
Bracket
Trough Flooring
Span of Trough Flooring about 14 ft. with the exception of 21st St. Bridge span of about 18 ft. 9 ins.
NOTE: This method of Sheathing to be used on the following Bridges:
Fifteenth Street Bridge; Seventeenth Street Bridge;
Eighteenth Street Bridge; Nineteenth Street Bridge;
Twentieth Street Bridge; Twenty-first Street Bridge.
Scale of Feet
0 5 10 15 20 25

FIG. 14.

cability of making any arrangements with the property owners as to the future adjustments of their buildings, the underpinning was made with rubble masonry laid in Portland cement mortar, the wall being flush with the face, and of the same thickness as the foundation, of the old building. This work was done in sections, the trench excavated in front of the buildings generally being 3 ft. wide. As fast as the underpinning was completed, a temporary sidewalk of yellow pine was placed over it, so as to interfere as little as possible with the access to the properties. This underpinning was paid for by the cubic yard, the price being $20. In this price was included all shoring, sheathing, excavation, and all appurtenances. It was very successfully carried on, without any injury whatever to the structures along the work.

Upon the completion of the underpinning, the excavation of the street was begun at a number of points. Before it was actually commenced, the street-car traffic, by agreement between the contractors and the Traction Company, was diverted to Twelfth St. by means of a loop. One of the large electric feeders of the Union Traction Company, consisting of a number of ducts surrounded by concrete, was located on the east side of the street. The Traction Company drove two rows of piles, opposite each other, on either side of the conduit, at intervals of about 12 ft., the piles being driven well below the new subgrade. Excavation was then made from pile to pile beneath the conduit, and a heavy cross-piece was placed beneath the conduit and bolted to the piles. This remained until the excavated material in the street was removed. Then a new excavation was made, a new conduit placed in it, new cables were drawn and connected up, and the old conduit was broken up and removed.

As the excavation proceeded, the new sewer was laid on the west side of the street, and all house connections were made to it. The water and gas mains were also lowered, and all connections were made to the house line. The streets were finally paved between the curb lines with granite blocks on a 6-in. concrete base, and the sidewalks generally with brick, except where some other class formerly existed.

Considerable delay was caused for some time by being unable to do away with the temporary railroad crossing on Hamilton St. When this track was finally abandoned, the travel was taken from Noble St. into the subway, and up the grade at Sixteenth St. on the temporary tracks again at Sixteenth and Hamilton Sts. The abandonment of the

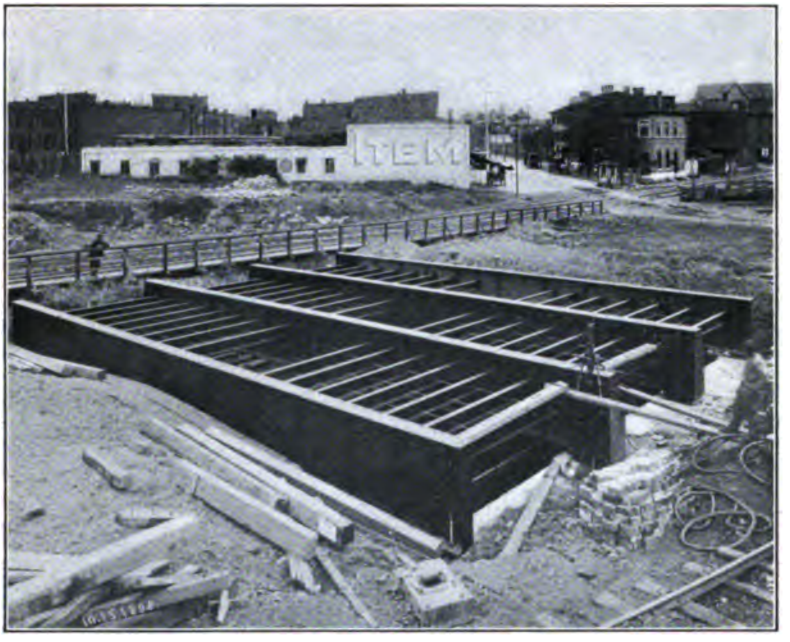


FIG. 1.—STEEL-WORK OF VENTILATION OPENING.

FIG. 2.—VENTILATION OPENING AT TWENTY-FIFTH STREET.

track crossing Thirteenth St. enabled the change of grade to be finished on that street and on Hamilton St., and the work completed on that contract.

The most interesting prices on this contract are shown in Table No. 13.

TABLE No. 13.

Excavation (unclassified)	$0.56 per cubic yard.
Rubble masonry, above neat line	6.00 " " "
Ashlar abutment masonry (rubble backing)	8.62 " " "
Coping (10 x 30 ins.)	2.25 per linear foot.
Rubble masonry underpinning, including excavation	20.00 per cubic yard.
Repaving with granite block on new 6-in. concrete base	1.50 per square yard.
Paving with granite block on 6-in. concrete base	2.75 " " "
Brick sidewalk paving	1.00 " " "
Sewer, 2 ft. 9 ins. diameter	2.25 per linear foot.
Sewer, 1 ft. 8 ins. diameter	2.00 " " "
Sewer, 2 ft. 6 ins. diameter	2.25 " " "
Yellow pine lumber in trestles, etc	27.00 per M. ft. B. M.
Steel-work in bridges at Twelfth and Thirteenth Sts., and adjustment of old work	36 695.00.

Work was started on this contract on November 12th, 1897, and final payment was made on November 28th, 1899. The total amount paid under the contract was $152 442.94.

Changes in Plan Between Sixteenth and Seventeenth Streets.

On account of the changes already referred to on Pennsylvania Ave., between Sixteenth and Seventeenth Sts., the contract with P. H. Flynn and Company was terminated on the south side of the street, and Contract 44 was executed with E. D. Smith and Company to complete the work on the revised plans. The work was paid for at unit prices, of which the following are of interest:

Tearing down old masonry	$1.00 per cubic yard.
Excavation, unclassified	1.00 " " "
Rubble masonry, below neat line	5.50 " " "
Rubble masonry, above neat line	6.00 " " "
Rock-faced ashlar, rubble backing	8 50 " " "

The total amount paid on this contract was $13 444.48.

Special Connection North of Nineteenth Street.

On the north side of the subway, between Nineteenth and Twentieth Sts., is located the works of a manufacturer of malleable and steel castings. After the plans were completed it was desired to con-

nect these works with the subway. Plans were prepared to connect with the tracks at the subway level by means of a hydraulic lift placed upon the property of the manufacturer. This lift was provided by the owner of the property, and its cost was included in his claim for damages. It is designed to lift a single car from the new to the old level, and is operated by a single vertical hydraulic cylinder. The City made all the excavations for the lift, dug the hole for the hydraulic cylinder, walled in the whole excavation, built a bridge on the line of the sidewalk on the high level, and reconstructed the building over the lift. The work was done under contract with E. D. Smith and Company (Contract 41), the total amount paid being $19 904.20.

Changes in Water and Gas Mains.

One of the most troublesome, and, in some cases, difficult parts of the work was the readjustment of the water and gas mains which were interfered with.

Water Mains.—On account of the necessity of having the changes at all times under the control of the proper municipal authorities, arrangements were made to advertise for the pipe, specials, valves, lead, gasket, etc., and have the actual work of making the changes performed by the employees of the Bureau of Water, the several contractors, however, making the necessary excavations and doing all the back-filling. The cost of the labor performed by the Bureau of Water was kept separate from their other work. The cost of the labor of making the changes hereafter described amounted to $34 579.35. The pipe and specials furnished under Contract 35 with the McNeal Pipe and Foundry Company amounted to $14 968.70, and the lead and gasket furnished under Contracts 36 and 39 amounted to $1 428.14, making the total cost of the water-pipe changes $50 976.19.

Outside of the relaying of several small mains caused by the change of grade of Thirteenth St., and the carrying of the 6, 8 and 10-in. mains over the bridges at Sixteenth, Eighteenth and Twentieth Sts., as well as other small mains west of Twenty-second St., the principal work was as follows:

Lowering the 30-in. mains on Broad St. to pass through the piers and abutments, and beneath the tracks; lowering a 6-in. main on Seventeenth St. in the same manner; excavating two tunnels through the rock on the east and west sides of Twenty-first St., before the core of

the subway was removed; placing a 48-in. and a 6-in. main in one, and a 20-in. and a 24-in. main in the other. These tunnels were driven at such a depth that when the pipes were laid and covered with 3 ft. of earth the top would be removed in excavating the core of the subway to subgrade, thus removing the rock from between the mains and the subgrade of the tracks.

An old line of 22-in. main on Pennsylvania Ave., laid in 1819, was removed, and a new line of 24-in. pipe was laid on the north side of the tunnel to replace it. The old pipe was found to be in remarkably good condition after 78 years of continuous service. The corrosion on the interior surface was found to displace about 4.2% of the original area.

From Twenty-second St. to the west the pipe lines cross the work over the top of the tunnel. Difficulty, however, was encountered on the line of Twenty-fourth St., Green St. and Fairmount Ave., where the mains are 48 ins. in diameter, in providing the necessary room between the top of the tunnel and the street above. The method of overcoming this difficulty has already been described.

Gas Mains.—The same general method of procedure was agreed upon with regard to the gas mains, but, before the work had advanced very far, the Gas-Works of the City were acquired under a lease with The United Gas Improvement Company, who were obligated, under their agreement, to make all the necessary changes. Under Contract 37, material to the value of $1 437.33 was furnished, but no account of the labor for making the necessary changes is available. On the line of Broad St. a 30-in. main was divided up into four 12-in. mains, and carried across the yard on the under side of the floor. The Gas Company also laid an additional 24-in. main beneath the tracks.

Permanent Tracks.

As fast as the excavation of the subway and tunnel was completed, and the subgrade prepared on the elevated portion of the work, the construction of the permanent tracks was begun by Contractors Ryan and Kelley, under Contract 30. The contract, besides covering all the trackwork of a permanent nature, included the removal of the temporary tracks and the restoration and repaving of such portions of the work as should be directed by the Chief Engineer. The trackwork proper, including the removal of the temporary tracks, was bid for in a lump sum, there being unit prices for all the work of street

restoration. All the material in the temporary tracks became the property of the contractor for the permanent tracks, and he was required to make allowance therefor in his bid on the work.

The four main tracks were required to be ballasted with good, hard, durable, broken stone, crushed or broken into fragments which would pass a 2½-in. ring in any direction, and be perfectly free from dirt or any other admixture before being spread. It was laid to the lines shown on the drawings, with a minimum depth of 8 ins. beneath the tie at any point. The specifications allowed the use of clean, hard, vitrified, blast-furnace slag, in place of the stone, in the yards and on sidings, but very little of it was used on the work, on account of the difficulty of procuring a satisfactory quality.

The four main tracks were laid with first-class, white oak ties, laid sixteen to each 30-ft. rail. For the sidings and yard tracks, the specifications allowed the use of 20% of second-class ties. First-class ties were 8½ ft. long, 7 ins. thick, and not more than 14 nor less than 7 ins. wide. Second-class ties were to be the same as first class, but not less than 6 ins. face.

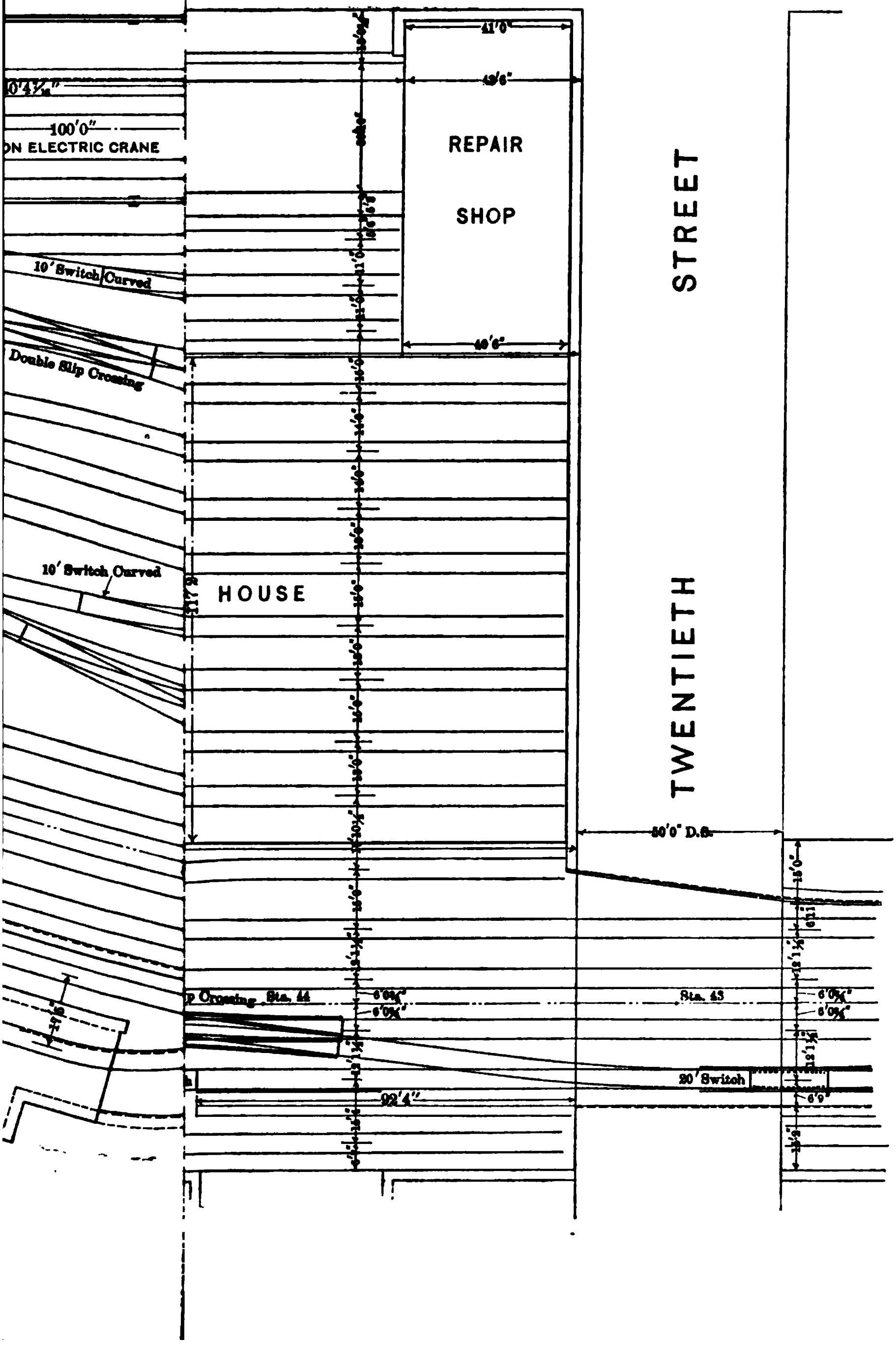
The rails of the four main tracks weigh 90 lbs. per yard, and the sidings and yard tracks, 80 lbs.; the sections for these weights being the standards of the Philadelphia and Reading Railway Company. The chemical composition of the rails is shown in Table No. 14.

TABLE No. 14.

Elements.	80-lb. rails.	90-lb. rails.
Carbon	0.55 to 0.60	0.60 to 0.65
Silicon	0.15 to 0.20	0.15 to 0.20
Manganese	1.10 to 1.30	1.15 to 1.35
Phosphorus	0.06	0.06
Sulphur	0.069	0.069
Rails having carbon below, will be absolutely rejected	0.53	0.58
Rails having carbon above, will be absolutely rejected	0.65	0.67

The drop-test required that one rail butt be taken from each heat, and that 90% of the specimens must stand without breaking, and that in cases where the broken butts do not show an elongation of 4% per inch under greatest tension, the rails of the heat are to be held until a piece can be cut from one and tested under the drop. Then, if it fails to show the 4% elongation before breaking, the entire lot of

PLATE VIII.
PAPERS AM. SOC. C. E.
MARCH, 1902.
WEBSTER AND WAGNER
ON PENNSYLVANIA AVENUE SUBWAY.



rails made from that heat shall be subject to rejection. The loads, height of drop, etc., were as follows:

Weight per yard.	Height of drop.	Distance of supports.
80 and 90 lbs.	20 ft.	3 ft.

All frogs, switches, spikes and other track details were made from the standard patterns and drawings of the railway company.

Before any material was ordered by the contractors, the City prepared working plans of the tracks, showing the definite location of all frogs, switches, special ties, etc. These plans were used by the contractor in ordering, by the engineers in the field in laying out the work, and by the contractors for the interlocking switches and signals. They proved to be of great value in expediting the work and preventing errors. Plate VIII shows this work in the Twentieth St. yard.

The tracks on the north side of the yard, between Thirteenth and Sixteenth Sts., as well as the two main tracks between these streets, were first completed, and, as fast as the subgrade was finished, two tracks were extended to the west through the subway and tunnel to the end of the work at Thirtieth St. The railway company then began carrying some of its regular freight business on these lines, and the work of removing a portion of the temporary tracks was begun. An effort was made to connect all the industrial establishments on the south side of the line with these tracks, so as to facilitate business. The last of the track laying was done in the freight yard at Twentieth St., and on the upper level of Sixteenth and Hamilton Sts. The last of the temporary tracks removed was on the high level between Twenty-sixth and Thirtieth Sts.

Hamilton St., for most of the distance between Broad St. and Pennsylvania Ave., was originally paved with cobble, and as it was decided during the construction of the work to repave it with new granite blocks, for which there was no price in this contract, arrangements were made to advertise for it under Contract 57.

Work was begun on this contract on August 1st, 1898, but, on account of the conditions existing on the other contracts, which prevented any large or continuous force being employed, it was not completed until September 9th, 1900.

The most interesting prices on the contract are as follows:

Track laying, with all appurtenances..........$209 453.00
Asphalt block repaving..................$2.50 per square yard.
Sheet asphalt paving, 6-in. concrete base.. 2.60 " " "

The total amount expended under the contract was $238 036.47.

The more important quantities embraced under the lump-sum bid are as follows:

27 584.21 ft. of single track with 80-lb. rail, ballasted.
41 244.26 " " " " 90 " " "
1 732.22 " " " " 80 " " on trestle.
1 560.00 " " " " 80 " " on timbers in engine-house.
2 226.01 " " " " 88 " tram rail laid in paved streets.
54 448 ft. of temporary track were removed.

Restoration of Hamilton Street.

The contractor for the permanent tracks, as part of his contract, was required to remove the temporary tracks from Hamilton St., and a contract was made with Michael O'Rourke (Contract 56) for restoring the paving, resetting old and furnishing new curb, reconstructing inlets and manholes, and replacing the industrial track connections crossing the street. The work was done at the following unit prices:

New granite block paving, 6-in. concrete base..$2.40 per square yard.
Resetting old curb............................ 0.25 " linear foot.
New crossing stones, 20 ins. wide.............. 1.00 " " "

There were also a large number of other items covering all classes of reconstruction, none of which is of special interest.

The total cost of the work was $36 541.70.

Guard Rails on 5% Inclines.

A contract, known as Contract 51, was entered into with Wilkins and Kuemmerle, which consisted in furnishing and laying additional guard rails on the metal approach from Twelfth to Callowhill Sts.; on the 5% grades beneath the bridges, and in some special cases in the yards. These guard rails, when planed to give 2¼ ins. between the heads, weigh 80 lbs. per yard. They were furnished at a cost of 40 cents per linear foot, while the same, unplaned, were furnished at 50 cents per foot. The total cost of this work amounted to $5 220.10.

Freight Bumpers.

The freight bumpers were of the Philadelphia and Reading standard, and were furnished under Contract 53 with Ryan and Kelley. They were of three kinds, and the prices for the bumpers, delivered and set in place, were as follows:

FIG. 1.—ELECTRIC CRANE, TWENTIETH STREET YARD.

FIG. 2.—WEST PORTALS OF SUBWAY AND BALTIMORE AND OHIO TUNNELS.

Standard high bumpers, 28 pieces, each.............	$200.00
" " " on trestle, 4 pieces, each...	156.60
" " " against walls, 6 pieces, each.	80.00

The same contract covered three special steel bumpers on the bridge at Sixteenth St., at a total cost of $1 525, and some additional items in connection with finishing the work at Sixteenth and Twenty-first Sts. The total payments for all the work on this contract amounted to $11 551.

Interlocking Switches and Signals.

The main tracks, from the connection with the tracks leading to the Reading Terminal to the east portal of the tunnel, are controlled by means of a complete system of interlocking switches and signals. This work was bid for in a lump sum, bids being asked upon a general specification requiring the submission of a general plan and detailed specifications with the bid. The work was awarded to Messrs. E. D. Smith and Company, who presented a plan and specifications prepared by the National Switch and Signal Company, of Easton, Pa. In the original specifications, either a manual or an electro-pneumatic system was stated to be satisfactory.

The scope of the work is best indicated by the description of the signal towers, which is as follows:

"Tower No. 1 on the west side of Broad St. will operate all switches and signals from the east of Thirteenth St. to a point west of Fifteenth St. This tower contains 51 active levers and 5 blanks (for future extensions) for the operation of—

35 switches,
5 movable-point frogs,
1 Scotch block,
34 facing-point locks,
32 signals.

"From the point west of Fifteenth St. to a point east of Twentieth St., switches will be operated from Tower No. 2, which is on the line of Seventeenth St. in a recess in the north abutment of the bridge. This tower contains a machine with 51 active levers and 5 blanks for the operation of—

35 switches,
5 movable-point frogs,
1 Scotch block,
11 locks,
34 facing-point locks,
32 signals.

"From the point east of Twentieth St. to the east portal of the tunnel, all the switches and signals are operated from Tower No. 3, which is located immediately east of Twenty-first St., which contains a machine having 75 active levers and 5 blanks for the operation of—

46 switches,
7 movable-point frogs,
10 locks,
50 facing-point locks,
44 signals.

The system used is a manual one, and the following are some of the principal features. The pipe line carriers were spaced 8 ft. apart, the wire pulleys 24 ft. apart.

Machines.—The levers are pivoted on a common center, spaced 5 ins. from center to center. The top plates and girders are made in sections for four and eight levers. The switch and lock levers are in the center. The locking is preliminary latch locking; the first act in the operation of the lever is to lock all conflicting levers.

The main pipe lines are $2\frac{3}{4}$ ins. between centers. The pipe is of iron or steel, 1 in. in diameter. All lengths of pipe of more than 100 ft. are compensated, and additional compensation is provided for all lengths of more than 700 ft. The compensator foundations are of oak, with concrete.

Detector bars are provided, as shown on the detailed plans, 45 ft. long, with 12 clips to each bar which rises $\frac{3}{4}$ in. above the top of the rail.

The wire is single-strand, No. 9, galvanized steel, the tensile strength being not less than 1 300 lbs. and the elongation from 4 to 8 per cent.

The signals are of standard semaphore type.

The contract price for all the foregoing work, completed and in place, was $85 000. The work was begun at the tower at Broad St., and was carried on as fast as the construction of the permanent track allowed. Work was begun on August 25th, 1898, and the final payment was made on July 5th, 1900. The total amount paid was $86 376.

In addition to the work of the interlocking, under this contract, the entire length of the subway is equipped with Hall automatic block signals, which were separately contracted for by the Philadelphia and Reading Railway Company.

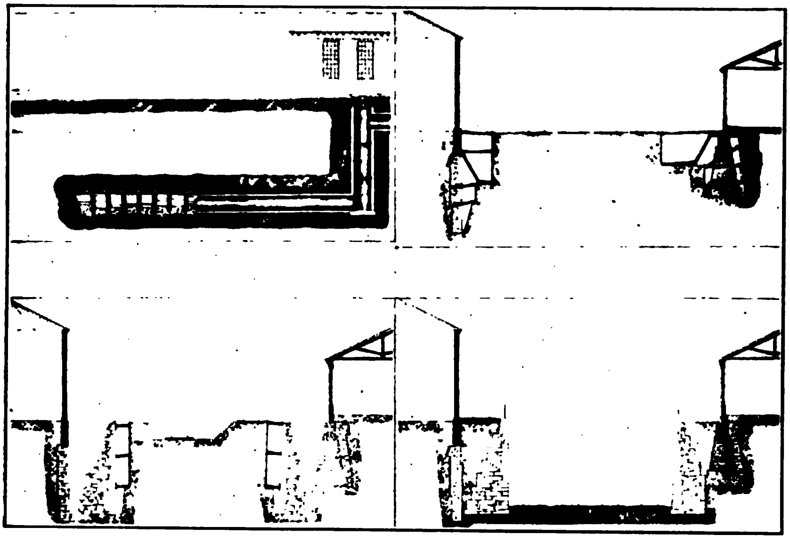


FIG. 1.—TYPICAL OPEN SUBWAY PROGRESS.

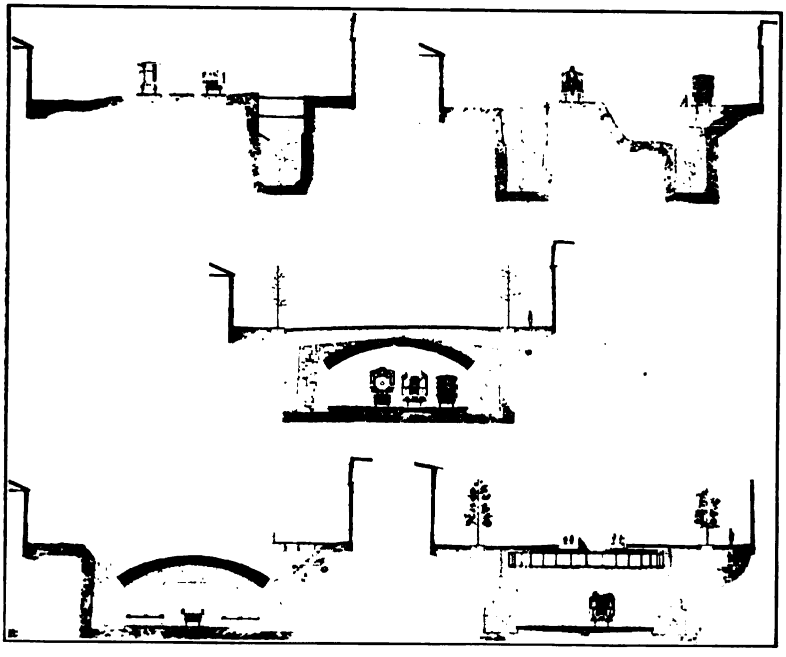


FIG. 2.—TYPICAL TUNNEL PROGRESS.

Telegraph Service.

During the construction of the work, the overhead telegraph wires were removed, a temporary cable was purchased, under Contract 38 with the Western Electric Company, and was laid by the Electrical Bureau in a City duct from Twelfth and Callowhill Sts. to Thirty-first St. and Girard Ave., entirely outside of the line of the work. The cable consisted of 40 wires of No. 16, B. & S. gauge, and 18 wires of the same gauge, twisted in pairs, all properly insulated and lead covered. Connections were made at the railroad offices at Sixteenth and Hamilton and at Twentieth and Hamilton Sts. There were 15 958 ft. of temporary cable, costing $4 468.24.

The permanent telegraph and telephone line was laid below ground in the subway in a three-duct creosoted conduit. As the capacity asked for by the railroad company was in excess of that which they originally had, a special agreement was made whereby the railroad company furnished the ducts, and the City, under the subway account, furnished the cable, the junction boxes, the manhole frames and the covers, and laid the cable by day's labor on the pay rolls of the Electrical Bureau.

The permanent cable consists of 10 wires of No. 14, B. & S. gauge, twisted in pairs, and 40 wires of No. 14, B. & S. gauge, insulated with manila rope paper, and lead covered. There were 11 272 ft. of cable, costing $5 083.68, which was furnished under Contract 55 with the Standard Underground Cable Company.

Coal Yard, Fifteenth and Callowhill Streets.

It was originally intended to construct a large coal-handling plant at Fifteenth and Callowhill Sts. The plans were modified at the suggestion of the railway company, and a coal yard was constructed under contract with Ryan and Kelley (Contract 49). The yard consists of a wooden coal trestle connecting with the high-level tracks at Sixteenth St. and Pennsylvania Ave., and provided with the necessary bins. An office and a two-story stable were included, and the yard was paved with granite blocks. The work was done under the following unit prices:

Stable	$2 700.00
Office building and scale	1 300.00
Track and trestle	2 950.00

Excavation, unclassified	0.75 per cubic yard.
Rubble masonry, above neat line...........	5.50 " " "
Rubble masonry, below neat line	5.00 " " "
Paving with granite block, sand base.......	1.75 " square yard.
Derailing switches in subway..............	50.00 each.

The total amount paid was $19 401.61.

Locomotive Coaling Station, Twentieth Street Yard.

Immediately to the west of the engine-house in the Twentieth St. yard, and located so as to span all the tracks leading therefrom, as well as the four main tracks in the subway, there is a locomotive coaling station, constructed under Contract 27 with the Link Belt Engineering Company.

It consists essentially of a storage pocket for coal and ashes, and a coaling bridge.

The storage pocket, 22 ft. wide, 52 ft. high and about 136 ft. long, is divided into two compartments. One compartment is for coal and the other is a pocket, 9 ft. 4 ins. wide and 20 ft. long, for ashes. The pockets are carried on steel posts supported on masonry piers. The framework is of steel sheathed on the inside with 3-in. closely matched, yellow pine, and on the outside with No. 22, galvanized, corrugated iron. The ash pocket is lined inside with concrete.

The coaling bridge consists of steel trusses, closed in and roofed over. It is provided with two lines of coaling tracks with turn-tables. There are six openings for discharging directly into locomotives and into two loading hoppers, each of 4 tons capacity. The coal elevator is of the gravity discharge type, with a capacity of 120 tons of coal per hour. The necessary engine power is included under the contract. The cost of the plant was $59 458.13.

Locomotive Water Supply.

The arrangements for supplying engines with water were included under Contract 50 with McParland and Butler, and consisted generally in furnishing four water columns, situated in the railroad yards, and making water and drainage connections to two others which were furnished by the railway company, which also supplied the tanks. The total cost of the work was $4 766.62. The principal items for payment on this contract were as follows:

FIG. 1.—COALING STATION, TWENTIETH STREET YARD.

FIG. 2.—FIVE PER CENT. GRADE TO SIXTEENTH STREET.

Excavation (not classified)............	$0.80	per cubic yard.
8-in. cast-iron pipe..................	0.47	" linear foot.
4 " " "	0.28	" " "
Water-columns, complete, each........	$590.00	

Freight-Houses.

Two terminal freight stations are included within the limits of the work: First, Broad St.; and second, Twentieth and Hamilton Sts.

Broad Street Station.—The station at Broad St. is a very important one. Before the construction of the Reading Terminal, in 1892, the main-line passenger station was located on Callowhill St., extending from Broad to Thirteenth Sts. To the north of it the freight station was located. After the abandonment of the passenger station, in 1893, the passenger building was used for freight purposes.

Upon the construction of the temporary tracks of the subway, the eastern half of these buildings was removed, and a temporary freight station at the north-west corner of Thirteenth and Callowhill Sts. was constructed, as before described. Upon its being occupied, the remaining old buildings were removed, and the excavation was made to the subway level for the western half of the block. A contract which had been entered into with Ryan and Kelley (Contract 15), was then begun, and the western halves of a double freight station were started and temporarily finished at the eastern end. As soon as it was completed and the tracks in the depressed yard were ready for operation, the remaining buildings, out to Thirteenth St., were finished.

The freight-houses, one for inbound and the other for outbound business, are of the following dimensions: One, 37 ft. wide, and 524 ft. long, and the other, 37 ft. wide and 465 ft. long. The buildings are of brick, with steel trusses and slate roofs, and are one story in height. At the Thirteenth St. end of the shorter building there is a three-story office building 43 ft. wide and 56 ft. 8 ins. long, with a cellar. Between the buildings there is a driveway 60 ft. wide, paved with granite blocks. At the east end the entrance is on a level with Thirteenth St. At the west end access to the buildings is obtained beneath the Broad St. Bridge and by means of the inclined approach, built on a 5% grade parallel to Callowhill St., reaching the street level at Fifteenth St. On the track side of each freight house there is a platform for loading and unloading freight.

Fire-walls are built in the houses at intervals, and are provided with rolling steel shutters. Shutters of the same type are also provided on the track sides of the buildings.

The work on this contract was bid for in a lump sum for the buildings. The paving of the driveway was bid for by the square yard. The total cost of the buildings was $98 251.20; the price for the paving was $3 per square yard. The total amount paid was $108 763.23.

Twentieth Street.—There are three buildings in the depressed yard at Twentieth St., as follows: A freight-house, an engine-house, and a repair shop. These were constructed by P. McManus, under Contract 25.

The freight-house consists of a two-story brick building 33 ft. wide and 308 ft. long, with a platform on the track side in the depressed yard and wagon access on the level of Hamilton St. Fire-walls between the elevators are provided with rolling steel shutters. Shutters of the same type are provided for the doors on the track side. Steel trusses, with a slate roof, cover the building. Five hydraulic elevators are provided for raising or lowering the freight from the street level to the subway. They have platforms, 10 x 14 ft. in the clear, and each is calculated to carry a load of 10 tons. They are designed to operate at a speed of 50 ft. per minute with a moderate load, and three of them, when fully loaded, are capable of rising 33 ft., the entire distance, at the same time. They are provided with automatic stops at the top and bottom, and with safety attachments and gates. All piping, pressure tanks and pumps are provided. The latter are located in the repair shop, and are in duplicate. The price bid for this building, complete, was $74 105.

Engine-House and Repair Shop.—The engine-house consists of a one-story brick building, 117 ft. wide and 200 ft. long, covering 8 tracks, and capable of housing 24 locomotives. The roof, consisting of wooden trusses, is covered with slate, and contains 24 Roe cast-iron smoke jacks, which have since been connected up to 3 smoke stacks, 125 ft. high, with electric fans at the bottom. Beneath the track there is an ash-pit lined with concrete, and transversely to the length of the building there is a pit for engine repairs. The drainage is into the low-level sewer on the line of Twentieth St. Steam heat, sufficient to heat the building to 50° Fahr. in the coldest winter weather, is provided from the boilers in the repair shop.

FIG. 1.—OVERHANGING DRIVEWAY AT EIGHTEENTH STREET.

FIG. 2.—GRAIN ELEVATOR AND CONNECTION AT NINETEENTH STREET.

The repair shop consists of a one-story brick building located in the corner of the depressed yard at Twentieth and Hamilton Sts., the retaining walls on the above-named streets forming two of the walls. It is 42 ft. wide and 82 ft. long, and contains two boilers, each of 175 H.-P., with two Argand steam blowers to burn buckwheat or rice anthracite coal. The boilers are guaranteed for a working pressure of 150 lbs. per square inch. Two duplex, boiler feed-pumps $5\frac{1}{4} \times 3\frac{1}{2} \times 5$ ins., are provided, together with a water-heater. Two 100 K.-W., compound-wound, multipolar, direct-current dynamos of 220 volts each, with a speed of not more than 700 revolutions per minute, are provided, each with a high-speed engine, and the whole plant is furnished with the necessary switch-board and all other appliances. These dynamos and engines are for the purpose of operating the 50-ton electric crane for raising heavy freight to the street level. The prices bid for the work were as follows:

Engine-house and repair shop	\$40 570
Boilers	11 255
Engines and dynamos	11 000

During the construction of the work, certain changes in the arrangement of the buildings were asked for by the railway company, entailing an additional cost of \$4 756. The total cost of the work on the freight-house, engine-house and repair shop, as described above, was \$141 999.80.

The contractor began work on April 25th, 1899, and finished on May 25th, 1900.

Proposed Power Lifts.

The power lifts, advertised for under Contracts 20 and 40, deserve more than a passing word of notice, on account of their size as well as of the engineering difficulties presented, and, although they were never constructed, the writers feel that their experience, as far as it went, may prove of interest.

In both contracts, simply the problem and the governing conditions were specified, and no design was made by the engineering force.

At one time two lifts were proposed, one at Seventeenth St. and the other at Nineteenth St., for the purposes already stated.

On account of the vigorous protest from the Philadelphia Grain Elevator Company, the lift at Nineteenth St. was abandoned, and the

connection was made by alterations in the grain elevator, and by a track reaching the plant on a 4% grade.

The specifications for the lift at Seventeenth St., under Contract 20, provide as follows:

"The hydraulic lift is to be located on the south side of Pennsylvania Ave., east of the Seventeenth St. bridge. Its object is to lift an engine and three cars from the level of the subway to the present level of Pennsylvania Ave. (about 26 ft.). It is to be designed, constructed, and erected complete, including excavations, foundations, structural steel work, machinery, pumps, pipes, and all appurtenances (except the ties and rails for the track) needed and required to make the plant complete and ready for operation.

"The contractor shall submit with his proposal complete drawings and specifications covering the general features described herein, which drawings and specifications, when accepted by the Director of the Department of Public Works, shall constitute an essential part of this contract, and shall be binding severally upon the contractor and the City of Philadelphia."

The lift was to have been 152 ft. in length, with a rise of 26 ft. 2 ins. and with a distributed load of 420 000 lbs., as a maximum.

The general specifications further provide that:

"It shall be designed so that it can lift all or any part of this loading in any position.

"In addition to the general plant shown on the plans, the contractor shall provide and include in his price a pumping plant or other machinery for operating the lift. Space will be provided for these pumps in the power-house between Eighteenth and Nineteenth Sts."

As a result of the advertisement of May 12th, 1896, six bids were received for the hydraulic lift (Contract 20). The prices ranged from $48 500 to $138 825 for the whole work erected complete. One bid was for an electric lift, at $59 970. No two of the plans submitted were upon exactly the same principle, the number of rams or screws varying from one to four.

The merits of all these lifts were examined carefully. As a result, all the bids were thrown out, and a new specification was prepared, under Contract 40, for a power lift. The general dimensions and loading were not changed. The essential features specified, as relating to the design, were as follows:

"In addition to the lift, the contractor shall provide and include in his proposal a complete plant of the machinery and apparatus necessary to operate the lift. The machinery generating power shall be in

duplicate. Space will be provided for the machinery in the power-house, to be located as shown on the general plan, on the south side of Pennsylvania Ave., west of Eighteenth St., on or about the present level of the street, and about 750 ft. west of the location of the lift.

"The city will provide boilers and their accompaniments, but the contractor for the lift shall provide and connect steam pipes to the main steam pipe in the boiler-room; also exhaust pipes to the feed-water heater, and main exhaust and drips from the pipes and the machinery operating the lift. He shall also provide covering for said pipes.

"A satisfactory means shall be furnished and constructed for conveying the power from said machinery in the power-house to the lift, and also a system of signals between the power-house and the lift to regulate the operation of the same.

"The contractor shall put the entire plant into operation, and supply everything for its proper service with the exception of the boilers and accompaniments.

"The following requirements shall be provided in all designs submitted, and the general methods for accomplishing the same shall be specified:

"*First.*—Absolutely uniform motion in the ascent and descent of the lift shall be maintained, and the platform kept horizontal under all conditions of loading.

"*Second.*—In case of accident of any kind, the platform shall come to a full stop in a horizontal position.

"*Third.*—Suitable protection shall be provided for the working parts of the lift, to prevent damage and wear from exposure to the weather, dirt, grit, water, etc.

"*Fourth.*—A method of operating the lift which can be controlled at the site will be preferred, all other things being equal.

"*Fifth.*—The lift, carrying the load under any condition, shall be capable of being raised or lowered throughout its entire vertical height in ten minutes.

"*Sixth.*—Special attention should be given to the design of the lateral stiffness of the lift, and the cost of making any attachments for the same to the masonry wall shall be included in the price bid.

"The preliminary drawing shall show such attachments, and any additions to the present masonry, if required.

"Should hydraulic power be proposed to be used, special attention is called to the distance of the power-house from the lift, and provision shall be made for the effects of the compression of the liquid used under the high pressures necessarily employed."

The work was again advertised, and, on March 30th, 1897, two bids were received for a hydraulic lift, $95 425 and $77 000, respectively, and two for an electric lift, $44 750 and $75 110.

An examination of the designs submitted showed them to be practically free from objectionable features, but all bids were again rejected on account of the purchase of the Whitney property by the railway company and the substitution of a 5¼% grade and a switchback in its place.

During the study of this matter, Table No. 15, giving a list of the then existing lifts, with their heights, pressures and loads, was prepared. Hydraulic power is used in all.

TABLE No. 15.

Name of lift and location.	Height, in feet.	Pressure.	Load, in tons.
Glasgow Harbor Tunnel	72	750 lbs.	6
Eiffel Tower	420	....	3.5
Weehawken	143	....	10.5
Mersey Tunnel	100	660 lbs.	7
Anderton, England, Canal	50	554 lbs.	510
Canal due Centre, Belgium	55.5	....	....
Les Fontinettes, France	43	....	300
Proposed Subway	26.25	2 000 lbs.	210

Fifty-Ton Electric Crane.

On the south side of Hamilton St., just east of Twenty-first St., there is located a 50-ton electric traveling crane, which was built under Contract 27 with E. D. Smith and Company.

The plant consists of two lines of runway girders supported upon columns, the total length of runway being 96 ft. One runway is located 14.6 ft. north of the retaining wall of the subway, on piers built to the elevation of Hamilton St. The other is situated 29.2 ft. south of the same wall, the tops of the piers being at the level of the tracks in the depressed yard and the bridge of the crane spanning two of the tracks. The crane is carried by two trucks on each runway, which are 15 ft. between centers. The distance from center to center of the runway girders is 43 ft. 10 ins. The crane was built by William Sellers and Company, Inc., and was designed upon the following data:

Capacity, 50 tons.
Maximum lateral speed of crane, 100 ft. per minute.
To hoist the maximum load to the full height in 4 minutes.
To raise the maximum load as frequently as may be desired.

The electrical cable connections with the dynamo were included under Contract 25. The distance from the subway tracks to the hook of the crane is about 56 ft.

The contract price for the crane, complete, including foundations, runway girders and all appurtenances, was $20 640.

Approximate Total Quantities.

The following list, of the total quantities of the more important items of the work, is given for the purpose of comparing the magnitude of the work with other work of a similar character:

Earth and rock excavation............	1 086 422 cu. yds.
Masonry (exclusive of sewers)	183 114 " "
Temporary track.....................	11.28 miles of single track.
Permanent track.....................	13.45 " " " "
Sewers..............................	7.02 miles.
Bridges.............................	18
Structural steel in bridges, etc.	10 515 787 lbs.
Number of approved drawings, not counting studies..................	1 354
Number of shop drawings, checked and approved......................	1 010

Consequential Damages and Financial Summary.

Under the terms of the Ordinance appropriating the $6 000 000 for the work, and authorizing its construction, it was provided that all the expenses incident to its completion, including consequential damages and the widening of Pennsylvania Ave. from Twenty-second to Green Sts. and from Green St. to Twenty-sixth St., were to be paid out of the appropriation.

Juries of View appointed by the Courts, in accordance with Acts of Assembly, were constantly engaged in hearing claims of property owners and tenants, numbering in all about 182 claims. The claims made and filed by these owners and tenants amounted to approximately $2 000 000.

Wherever it was possible, no claims for change of grade were considered by the Juries until the physical changes were completed, so that there could be no speculation as to the exact nature of the damage. On this account, various sections of the work were considered as the work of construction advanced, and awards were made in advance of other sections where the work was still in progress.

The following is a concise statement of all expenditures made on account of the work:

Total amount paid for contracts (including sewers*)	$4 067 482.15
Paid by mandamus for land and consequential damages	1 040 345.71
Fees for expert testimony in damage cases	29 185.05
Fees of Road Jurors in damage cases	3 826.00
Labor—Water, Gas and Electrical Bureaus	41 102.00
Engineering, inspection and incidentals	227 422.51
Total expenditures to December 31st, 1901	$5 409 363.42
Balance on hand December 31st, 1901	15 636.58
Total amount of loan negotiated	$5 425 000.00
Amount of loan not sold	575 000.00
Total appropriation	$6 000 000.00

Summary of Construction Dates.

The work of constructing the sewers was begun on September 10th, 1894, and by July 1st, 1895, the main sewers were completed. No construction work was then done until August, 1896, when the temporary track work was started. The first regular passenger train, carrying the members of the American Society of Civil Engineers on their way home from the Annual Convention at Cape May, passed through the subway on July 1st, 1899, and on September 25th of the same year the regular traffic of the railway was begun. By November, 1900, the work was practically completed, except a few minor details.

Engineering.

The ordinance authorizing the work provided that it was to be organized and carried out by the Director of the Department of Public Works of the City of Philadelphia, who has supervision of the Engineering Bureaus of that city. The Directors under whom the work was carried out were as follows: From September, 1894, to April, 1895, Hon. James H. Windrim, under Hon. Edwin S. Stuart, as Mayor. From April, 1895, to April, 1899, Hon. Thomas M. Thompson, under Hon. Chas. F. Warwick, as Mayor. From April, 1899, until the completion of the work, Hon. Wm. C. Haddock, under Hon. Samuel H. Ashbridge, as Mayor.

* For sewers, see *Transactions*, Am. Soc. C. E., Vol. xliv, page 1 *et seq.*

PLATE XIII.
PAPERS AM. SOC. C. E.
MARCH, 1902.
WEBSTER AND WAGNER
ON PENNSYLVANIA AVENUE SUBWAY.

FIG. 1.—SUBWAY, EAST FROM SIXTEENTH STREET.

FIG. 2.—SUBWAY, WEST FROM SIXTEENTH STREET.

The entire charge of the preparation of the plans and the construction was placed under George S. Webster, M. Am. Soc. C. E., Chief Engineer, Bureau of Surveys, which Bureau has jurisdiction over such work. Mr. George E. Datesman is Principal Assistant Engineer of this Bureau.

In June, 1894, Samuel Tobias Wagner, M. Am. Soc. C. E., was appointed First Assistant Engineer in charge of the work, and Mr. Charles H. Swan, Chief Draughtsman.

In August, 1894, Mr. Richard I. D. Ashbridge was appointed Second Assistant Engineer in charge of the construction of the sewers.

When active work on the main operations was begun in August, 1896, the field corps was organized with D. Jones Lucas, M. Am. Soc. C. E., as Second Assistant Engineer in charge of construction, and Mr. R. I. D. Ashbridge as Third Assistant Engineer in charge of the lines and grades. The principal Assistants under Mr. Ashbridge during construction were Mr. Frank R. Fisher, Mr. John W. Weaver, T. N. Spencer, Assoc. M. Am. Soc. C. E., and Mr. Stephen Harris. To all of these gentlemen great credit is due for skill and accuracy.

Under the Ordinance, the Director of the Department of Public Works is directed to confer, during the progress of the work, with an engineer appointed by the Philadelphia and Reading Railroad Company in regard to the approval of all plans and the proper execution of the contracts. The late John A. Wilson, M. Am. Soc. C. E., served in the capacity of Consulting Engineer from March 30th, 1894, until his death on January 19th, 1896. Mr. Wilson was closely identified with the preparation of all the detailed studies of the work previous to the passage of the Ordinance. Upon the death of Mr. Wilson, Mr. Joseph M. Wilson, M. Am. Soc. C. E., was appointed Consulting Engineer, and served until the completion of the work.

During the entire time, the principal officers of the Philadelphia and Reading Railroad Company were: Mr. Joseph S. Harris, President; Theodore Voorhees, M. Am. Soc. C. E., First Vice-President; Mr. H. K. Nichols, Chief Engineer, and William Hunter, M. Am. Soc. C. E., Assistant Chief Engineer.

To all the above-mentioned gentlemen the writers desire to acknowledge the kind assistance, advice and courtesy at all times rendered during the preparation of the plans and the carrying out of all the details of the work.

				Date of proposal.						
8	Tearing down old houses at Pennsylvania Ave. and Pagoda St..........	Geo. W. Ruch......	Mar. 18, '95	Mar. 18, '95	Mar. 27, '95	30 days	Apr. 27, '95	400.00	400.00	Apr. 9, '95
9	Removing surplus material on Wood St., and paving and repaving sidewalks...............	This contract was never executed. The work was done by C. P. Grim & Co. as part of Contract No. 1.								
10	Tearing down old houses and stable at No. 2427 Pennsylvania Ave......	Geo. W. Ruch......	Oct. 28, '95	Oct. 28, '95	Oct. 31, '95 Verbal order.	10 days	Nov. 10, '95	85.00	85.00	Nov. 12, '95
11	Temporary tracks........	P. McManus........	May 12, '96	Aug. 3, '96	Aug. 10, '96	3 months	Nov. 3, '96	150 000.00	144 098.99	July 12, '98
12	Work from south side of Callowhill St. to the west house line of 13th St., including changes of grade of 13th and adjacent streets...........	P. H. Flynn & Co..	May 12, '96	Sep. 8, '96	Oct. 1, '97	18 months	Apr. 1, '99	225 000.00	152 442.94	Nov. 28, '99
13	Construction of retaining walls and abutments on the north side of Callowhill St., between 13th St. and a point near 16th St., and on the south side of Noble St., from 13th to Broad Sts...............	E. D. Smith & Co..	May 12, '96	Sep. 4, '96	Sep. 23, '96	18 months	Mar. 23, '98	85 000 00	84 995.66	May 17, '98
14	Excavation of core from Sta. 10+9 to Sta. 51, including construction of bridges, grading and repaving of approaches, etc......................	E. D. Smith & Co..	May 12, '96	Sep. 4, '96	Apr. 15, '97	18 months	Oct. 15, '98	765 000.00	736 088 92	Oct. 5, '99
15	Construction of freight-houses, between 13th and Broad Sts..........	Ryan & Kelley....	May 12, '96	Apr. 26, '97	May 16, '98	9 months	Feb. 16, '99	113 000.00	108 763 23	Oct. 16, '99
16	Construction of retaining walls, and reconstruction of Block "A" on the north side of Pennsylvania Ave., between Broad and 15th Sts......	M. McManus.......	May 12, '96	Sep. 10, 96	Apr. 1, '97	3 months	July 1, '97	28 000.00	24 295.21	Dec. 31, '97

TABLE No. 16.—LIST OF CONTRACTS, PENNSYLVANIA AVE. SUBWAY AND TUNNEL, ACCORDING TO ORDINANCE OF MARCH 17TH, 1894.

No.	Description of contract.	Name of contractor.	Date of letting.	Date of contract.	Notice to begin work.	Time limit.	Time expires.	Limit of contract.	Total amount paid.	Final payment.
1	Sewer on Wood St., 24th St. and Powelton Ave., and on Callowhill St. from the Schuylkill River to Sta. 19 with appurtenant sewers on 22d St., Hamilton St. and Pennsylvania Ave......	C. P. Grim & Co...	Aug. 30, '94	Sep. 4, '94	Sep. 10, '94	4 months	Jan. 10, '95	$94 000.00	$80 342.75	Aug. 19, '96
2	Sewer on Callowhill St., from Sta. 19 to Sta. 38, with appurtenant sewers on 17th, 18th, 19th and 20th Sts............	Geo. W. Ruch.....	Aug. 30, '94	Sep. 5, '94	Sep. 10. '94	4 months	Jan. 10, '95	75 000.00	8 705.13 60 957.58	Mandamus Dec. 4, '97 Jan. 26, '97
3	Sewer on Callowhill St., from Sta. 38 to 13th St., and on 13th St., from Carlton St. to Buttonwood St., with appurtenant sewers on Callowhill, 15th and 16th Sts.....................	J. McCann.........	Aug. 30, '94	Sep. 4, '94	Sep. 10, '94	4 months	Jan. 10, '95	47 000 00	35 976.81	June 26, '95
4	Sewer on Powelton Ave., 24th St. and Pennsylvania Ave,, from the Schuylkill River to Sta. 19 + 88................	Ryan & Kelley.....	Aug. 30, '94	Sep. 4, '94	Sep. 10, '94	4 months	Jan. 10, '95	102 000.00	92 586.42	June 29, '95
5	Sewer on Pennsylvania Ave., from Sta. 19 + 88 to 30th St..............	J. A. Mundy & Bro.	Aug. 30, '94	Sep. 4, '94	Sep. 10, '94	4 months	Jan. 10, '95	138 000.00	126 496.15	May 31, '95
6	Sewer on 12th St., Buttonwood St., and on 13th St., from Whitehall St. to Carlton St...........	J. McCann.........	Aug. 30, '94	Sep. 4, '94	Sep. 10, '94	4 months	Jan. 10, '95	25 000.00	22 823.49	Jan. 29, '95
7	Test pits on Pennsylvania Ave.....................	J. McCann.........	Jan. 28, '95	Feb. 12, '95	Feb. 16, '95	10 days	Feb. 26, '95	475.00	174.77	Oct. 23, '95

	Freight, engine, and repair houses in Twentieth St. yard	P. McManus	May 12, '96	Aug. 11, '97	Apr. 24, '99	10 months	Feb. 24, 1900	142 000.00	141 999.86	....
26	Locomotive coaling station in Twentieth St. yard	Link Belt Eng. Co.	May 12, '96	Oct. 17, '96	July 12, '99	7 months	Feb. 12, 1900	60 000.00	59 458.18	Nov. 14, 1900
27	Electric crane in Twentieth St. yard	E. D. Smith & Co.	May 12, '96	Dec. 30, '96	Nov. 19, '98	24 months	Nov. 19, 1900	22 000.00	20 640.00	Nov. 28, '99
28	Construction of retaining walls, and reconstruction of Block "Q" on south side of Pennsylvania Ave., between 21st and 22d Sts.	E. D. Smith & Co.	May 12, '96	Sep. 4, '96	Sep. 23, '96	18 months	Mar. 23, '98	17 000.00	16 284.20	Apr. 1, '99
29	Work from Sta. 51 to Sta. 100, including tunnel and ventilation conduits, etc., but not fan stations. A final contract, except permanent tracks	This contract was	not awarde	d, on account	of change	of plans. R	e-advertise	d as No. 33.	....	....
30	Permanent tracks, including tearing up of temporary tracks, paving Hamilton St., engine turn-table	Ryan & Kelley	May 12, '96	May 3, '97	June 1, '98	4 months	Oct. 1, '98	260 000.00	238 036.47	Sep. 9, 1900
31	Signal plant	E. D. Smith & Co.	May 12, '96	July 19, '98	Aug. 11, '98	18 months	Feb. 11, 1900	90 000.00	86 376.00	July 5, 1900
32	Tearing down houses on Pennsylvania Ave., between Pagoda St. and coal yard formerly occupied by Garber & Son	Geo. W. Bush	Mar. 9, '96	Mar. 9, '96	Mar. 11, '96	5 days	Mar. 16, '96	99.50	99.50	Mar. 16, '96
33	Work from Sta. 51 to Sta. 100, including tunnel and subway. A final contract, except permanent tracks	E. D. Smith & Co.	Sep. 1, '96	Oct. 8, '99 Feb. 9, '97	Mar. 6, '97	18 months	Sep. 8, '98	15 000.00 1 000 000.00	1 014 992.97	June 5, 1900
34	Commercial coal conveyor	This contract was	never prep	ared. Contr	act No. 49	substituted	therefor.	....	....	....
35	Water pipe	McNeal Pipe and Foundry Co.	Oct. 27, '96	Nov. 24, '96	....	30 days	....	15 000.00	14 968.70	Mar. 21, '99
36	Lead	Wm. J. Ashmead	Oct. 27, '96	Dec. 10, '96	....	As wanted	....	2 000.00	1 868.85	Oct. 19, '97
37	Gas pipe	McNeal Pipe and Foundry Co.	Oct. 27, '96	Nov. 24, '96	....	30 days	....	6 500.00	1 437.33	July 5, '99

TABLE No. 16—(*Continued*).

No.	Description of contract.	Name of contractor.	Date of letting.	Date of contract.	Notice to begin work.	Time limit.	Time expires.	Limit of contract.	Total amount paid.	Final payment.
17	Construction of retaining walls, and reconstruction of Blocks "B" and "K," Pennsylvania Ave., between 15th and 16th Sts.	P. H. Flynn & Co.	May 12, '96	Sep. 8, '96	Mar. 29, '97	18 months	Sep. 29, '98	103 000 00	100 741.82	Oct. 21, '98
18	Commercial coal conveyor	This contract was	not awarde	d. Design n	ot satisfact	ory to the	P. & R. R.	R. Re-adve	rtised as No.	34.
19	Construction of retaining walls, and reconstruction of Blocks "C" and "L" on Pennsylvania Ave., between 16th and 17th Sts.	P. H. Flynn & Co.	May 12, '96	Sep. 8, '96	Sep. 23, '96	18 months	Mar. 23, '98	138 000.00	108 018.49	July 13, '99
20	Hydraulic lift	This contract was	not awarde	d, on account	of change	of plans. R	e-advertise	d as No. 40	....	....
21	Construction of retaining walls, and reconstruction of Blocks "D" and "M" on Pennsylvania Ave., between 17th and 18th Sts.	P. H. Flynn & Co.	May 12, '96	Sep. 8, '96	Sep. 23, '96	18 months	Mar. 23, '98	115 000.00	105 557.70	June 10, '98
22	Construction of retaining walls, and reconstruction of Blocks "E" and "N" on Pennsylvania Ave., between 18th and 19th Sts.	P. H. Flynn & Co.	May 12, '96	Sep. 8, '96	Sep. 23, '96	18 months	Mar. 23, '98	88 000.00	72 102.12	Law case.
23	Construction of retaining walls, and reconstruction of Blocks "F" and "O" on Pennsylvania Ave., between 19th and 20th Sts.	E. D. Smith & Co.	May 12, '96	Sep. 4, '96	Sep. 23, '96	18 months	Mar. 23, '98	82 000.00	68 812.63	Law case.
24	Construction of retaining walls, and reconstruction of Blocks "P," "G" and "H" on Pennsylvania Ave., between 20th and 21st Sts.	P. H. Flynn & Co.	May 12, '96	Sep. 8, '96	Sep. 23, '96	18 months	Mar. 23, '98	146 000.00	145 782.61	Feb. 9, 1900

55	Permanent telegraph line	The Standard Underground Cable Co..............	May 3, '99	June 8, '99	June 20, '99	3 months	Sep. 20, '99	7 500.00	5 083.68	Oct. 31, '99
56	Paving, repaving, curb setting and appurtenant work on Hamilton and adjacent streets....	Michael O'Rourke.	Sep. 19, '99	Nov. 1, '99	Nov. 18, '99	4 months	Mar.18, 1900	45 000.00	36 541.70	Aug. 10, 1900
57	Protection and painting of bridges and other work..................	Ryan & Kelley....	Mar. 13, 1900	Mar. 21, 1900	May 15, 1900	5 months	Oct. 15, 1900	32 000.00	27 517.95	Dec. 26, 1900
58	Underpinning and adjustment to building. Hoopes & Townsend...	John Mitchell.....	Dec. 18, '99	Dec. 22, '99	Mar. 8, 1900	60 days	May 17, 1900	4 000.00	2 345.44	June 19, 1900
59	Electrical, cast-iron manhole frames and covers.	The Greger Mfg. Co............	Dec. 19, '98	Oct. 11, '99	....	As wanted	....	1 200.00	991.49	Nov. 28, '99
60	Painting upper deck, 16th St. railroad bridge......	J. W. Webber......	Oct. 14, '99	No contract.	Oct. 20, '99	7 days	Oct. 27, '99	50.00	50.00	Dec. 5, '99
61	Automatic safety gates for elevators in 20th St. freight-house..........	Ryan & Kelley....	Oct. 2, 1900	Oct. 26, 1900	Jan. 5, '01	60 days	Mar. 5, '01	2 000.00	1 489.00	Apr. 26, '01
								Total	$4 067 482.15	

TABLE No. 16—(*Concluded*).

No.	Description of contract.	Name of contractor.	Date of letting.	Date of contract.	Notice to begin work.	Time limit.	Time expires.	Limit of contract.	Total amount paid.	Final payment.
38	Telegraph cable	Western Electric Co.	Oct. 27, '96	Nov. 27, '96	Dec. 9, '96	30 days	Jan. 8, '97	6 500.00	4 468.24	Mar. 23, '97
39	Gasket, jute packing, coke, etc	J. F. Hazard & Co., Inc. Uhler and English	Nov. 11 '96	No contract.	....	As wanted	....	....	English 28.33 Hazard 35.96	Apr. 23, '97 Apr. 7, '97
40	Power lift	....	Mar. 30, 97	This contract not awarded. Lift abandoned.				....	....	....
41	Permanent track connection, Block "F"	E. D. Smith & Co.	Aug. 24, '97	Sep. 1, '97	Sep. 13, '97	4 months	Jan. 13, '98	24 000.00	19 904.20	May 17, '98
42	Trestle and temporary tracks	E. D. Smith & Co.	Aug. 24, '97	Sep. 1, '97	Sep. 15, '97	2 months	Nov. 15, '97	29 000.00	19 049.18	Nov. 1, '98
43	Cast-iron gas pipe, valves and fittings	Camden Iron Works, Frank W. Dilks & Co.	Nov. 1, '97	Dec. 16, '97 Dec. 4, '97	Dec. 22, '97 Dec. 15, '97	1 month	Jan. 22, '98 Jan. 15, '98	A 1 200.00 B 450.00	897.31 422.00	May 24, '98 Dec. 29, '97
44	Retaining walls, grading, and other work, Block "L"	E. D. Smith & Co.	Mar. 3, '98	Apr. 12, '98	Apr. 18, '98	4 months	Aug. 18, '98	18 000.00	13 444.48	Jan. 24, '99
45	Construction of the work appurtenant to the temporary track connection from Hamilton St. to the Baldwin Locomotive Works	E. D. Smith & Co.	Dec. 21, '97	Jan. 12, '98	Jan. 15, '98	30 days	Feb. 15, '98	8 500.00	6 075.40	Mar. 6, 1900
46	Bridge railings	The North Penn. Iron Co.	Mar. 3, '98	May 3, '98	May 7, '98	90 days	Aug 4, '98	6 000.00	4 941.51	Sep. 22, '99
47	Galvanized pipe for electrical conduits	Whetstone & Co.	Jan. 18, '98	Apr. 1, '98	....	....	....	1 600.00	1 539.83	Apr. 15, '98
48	Railroad yard	Gordon Chambers.	June 28, '98	July 30, '98	Aug. 10, '98	90 days	Nov. 25, '98	1 900.00	1 900.00	July 31, 1900
49	Coal yard, 15th and Callowhill Sts.	Ryan & Kelley	Feb. 23, '99	Mar. 2, '99	Apr. 10, '99	4 months	Aug. 10, '99	24 000.00	19 401.61	Apr. 24, 1900
50	Permanent water supply.	McParland & Butler	Sep. 6, '98	Sep. 29, '98	Nov. 7, '98	30 days	Dec. 7, '98	7 500.00	4 766.62	Oct. 24, '99
51	Guard Rails for permanent tracks	Wilkins & Kuemmerk	Sep. 6, '98	Oct. 1, '98	Nov. 4, '98	60 days	Jan. 17, '99	6 000.00	5 220.10	July 24, 1900
52	Coal hopper pit. Bement. Miles & Co.	Stacy B. Opdyke, Jr.	Feb. 23, '99	Mar. 9, '99	Apr. 22, '99	3 months	July 22, '99	6 000.00	4 081.69	Oct. 6, '99
53	Railroad bumpers	Ryan & Kelley	May 3, '99	May 26, '99	July 1, '99	4 months	Nov. 1, '99	14 000.00	11 551.00	May 9, 1900
54	Repaving and temporary curb	....	Dec. 13, '98	....	....	....	....	....	....	....

Vol. XXVIII. MARCH, 1902. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

STRESSES IN COLUMNS SUBJECT TO COMBINED AXIAL AND TRANSVERSE LOADING.*

By Charles Worthington, M. Am. Soc. C. E.

The most common examples of columns of this class are those supporting elevated railroads, roofs of mill buildings, posts of portals, etc.

The common method, of assuming that the lower end of such columns be "fixed," and determining the bending stress in the columns by the elastic-curve formulas on this assumption, has never appeared to the writer as a satisfactory solution of the problem. In the first place, the condition of "fixity," as assumed in determining these formulas, is not present. If the foundation pedestal were of steel, and the column extended down into it sufficiently far, and without any play whatever, the column could then be assumed as fixed at its base in accord with the conditions assumed in these formulas, but the critical point would only be transferred from the bottom of the column to the bottom of the pedestal, and as most pedestals rest on material which is quite soft compared with their own, considerable deflection would occur before the pedestal reached a firm bearing. The anchor bolts, also, are assumed to increase the fixity of the column base,

* This paper will not be presented for discussion at any meeting, but its discussion may be called up at any time, and written communications on the subject are invited for presentation to the Society and for subsequent publication.

whereas they do not come into play until there has been sufficient deflection of the column to bring the base to a firm bearing against the nuts, and to stretch the bolts themselves, if they are of any great length. On account of the lack of rigidity at the bottom of the column and at the bottom of the pedestal, therefore, the bending of the column does not follow the lines given by the deflection formulas based on "fixity" of the end.

This assumption, moreover, fixes at once the size of the masonry pedestal, and leaves no chance to vary its size to suit local conditions, whereas, for example, in designing an elevated railroad through city streets, it is quite often necessary to limit the size of the pedestal, in order to clear conduits, etc., already in place, no matter how much additional material this may require in the superstructure. It is desirable, therefore, that the connection of the column to the pedestal be such that the size of each may be varied in order to strike a balance between the cost of the column and the cost of the pedestal, with a view to maximum economy for the structure as a whole.

Another factor which is neglected in the foregoing method is the effect of the direct axial load on the bending of the column. As soon as the column starts to bend under the horizontal load, the windward side of the base rises, thus tending to shift the point of bearing of the column on the pedestal to the opposite side, thereby producing a bending in the column in a direction counter to that produced by the horizontal load, and directly proportional to the amount of the axial load. With a view to establishing the exact relations between these forces and their effect on the column and the pedestal, the writer has prepared this paper.

The general type of column under consideration is illustrated in Fig. 1, which represents the outline of a column with a square base, anchored down to a pedestal of masonry, and supporting a vertical load, with horizontal forces applied, one at the top, and one in the opposite direction at a point below, representing the force produced by a knee-brace, or strut of some kind. For purposes of analysis, the different forces and reactions, with the resulting stresses produced in the column, will be determined separately, and then combined for the total net results.

Considering first the horizontal forces alone acting, Fig. 2 shows the effect on the column of a horizontal force, H, which is the total

horizontal thrust coming on the top of the masonry, from wind, traction, etc., acting on the structure of which this column forms a part. The forces, at the top and at the point, X_1, of the amounts indicated, are those necessary to hold the column in equilibrium against this force, H, applied at the base, and the column will tend to bend as shown. The moment of the external forces about any point on the neutral axis of the column, distant x from the base (clockwise moments being considered positive and those in the opposite direction negative), will be

$$-Hx \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

and this moment will be a maximum at X_1, where its value will be

$$-Hb \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1\,a)$$

To the column thus bent, now consider the vertical load applied at the top. The column being lifted from the masonry at the windward side, the center of bearing on the masonry will be at the opposite corner, and this will produce in the column a moment in a direction opposite to that of the horizontal force, tending to counteract this force and tending to bend the column back at its lower end, as shown in Fig. 3. In fact, the deflection of the column from the horizontal force will be so slight that the distance, c_1, can be taken as equal to d, the half-width of the column, without any appreciable error. The moment of the external forces, about any point on the neutral axis of the column between the base and X_1, will be constant, and of the value

$$+Pd \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Finally, the effect of the anchor bolts is shown in Fig. 4, where A represents an assumed force which the bolts on one side of the column will be finally designed to resist. The moment of the external forces at any point on the neutral axis of the column, between its base and X_1, will be constant, and of the value

$$+Ae \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Summing up (1), (2) and (3), the total resultant moment, at any point on the neutral axis of the column between the base and X_1, and making $c_1 = d$, as above, will be (see Fig. 5)

$$M = -Hx + Pd + Ae \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

and the column section at this point must be designed to resist this moment, M, in combination with a uniformly distributed direct compressive stress, of the value P. In practice, columns of this class are

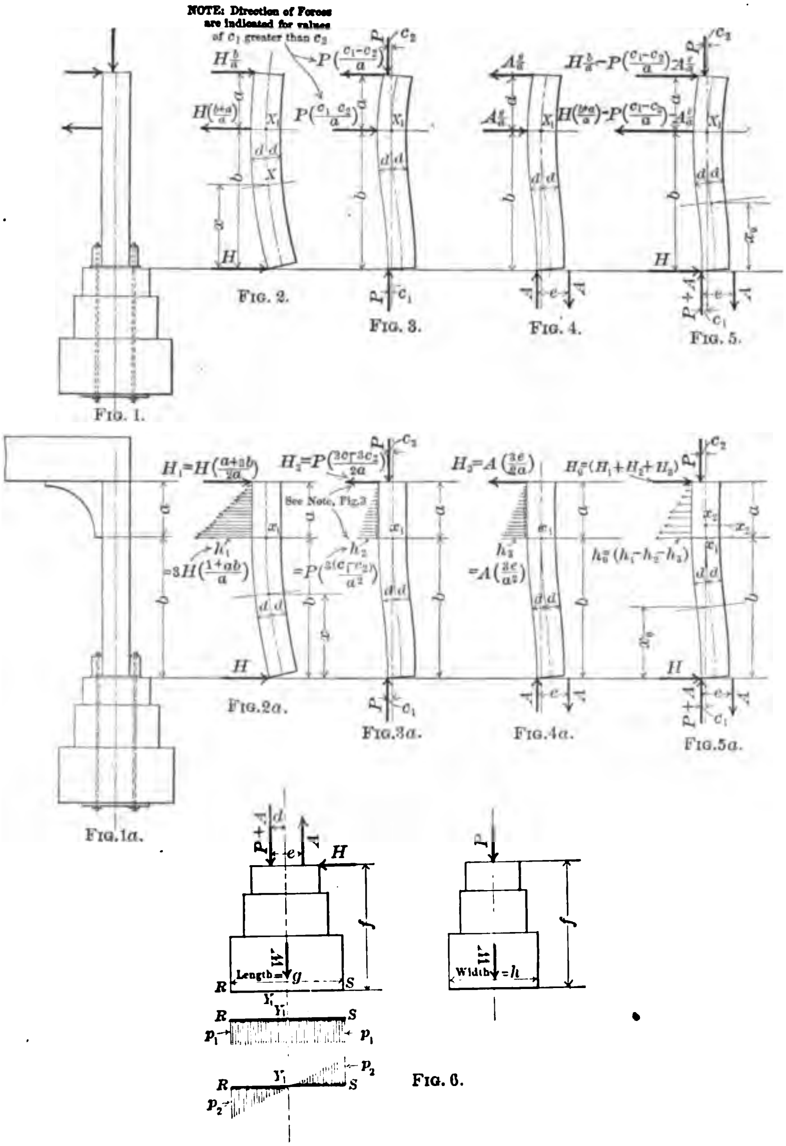


FIG. 1. FIG. 2. FIG. 3. FIG. 4. FIG. 5.

FIG. 1a. FIG. 2a. FIG. 3a. FIG. 4a. FIG. 5a.

FIG. 6.

generally made uniform in section throughout their length; in which case only the maximum moment, occurring at X_1, will be required, and this will be of the value

$$M_1 = -H\,b + P\,d + A\,e \quad\ldots\ldots\ldots\ldots\ldots\ldots(4a)$$

The section of the column should be such that the total compressive stress on the extreme fibers at this point will not exceed a certain allowable unit value.

The "point of contraflexure" will occur where $M = 0$; from which the distance from the base of the column to this point will be

$$x_0 = \frac{P\,d + A\,e}{H} \quad\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

This is of no especial value, except for comparison with that method of designing columns of this class in which the location of the point of contraflexure is assumed at the start, and the column, anchorage, etc., is then designed to correspond.

The resultant force at the top of the column, for which suitable provision must be made, is, (assuming that $c_1 = d$, as before),

$$H\frac{b}{a} - P\left(\frac{d - c_2}{a}\right) - A\frac{e}{a} \quad\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

If provision be made to ensure the load, P, being applied to the top of the column at its center, so that $c_2 = 0$, this force becomes

$$\frac{b}{a} - P\frac{d}{a} - A\frac{e}{a} \quad\ldots\ldots\ldots\ldots\ldots\ldots(6a)$$

If the superstructure is connected to the top of the column so that the point of application of the load, P, shifts to one corner as the column bends under the application of H, then c_2 becomes equal to d, and this force becomes

$$H\frac{b}{a} - A\frac{e}{a} \quad\ldots\ldots\ldots\ldots\ldots\ldots(6b)$$

The forces given by Formulas (6), (6a) and (6b) represent also, in each case, the shear for which the web of the column and the rivets connecting it with the flanges must be designed, from the top down to the point X_1.

The force at X_1, for which provision must be made in connections, etc., is (assuming $c_1 = d$, as before),

$$H\left(\frac{b + a}{a}\right) - P\left(\frac{d - c_2}{a}\right) - A\frac{e}{a} \quad\ldots\ldots\ldots\ldots(7)$$

When $c_2 = 0$, corresponding with the conditions of Formula (6a), this force becomes

$$H\left(\frac{b + a}{a}\right) - P\frac{d}{a} - A\frac{e}{a} \quad\ldots\ldots\ldots\ldots\ldots\ldots(7a)$$

And when $c_2 = d$, corresponding with the conditions of Formula (6*b*), this force becomes

$$H\left(\frac{b + a}{a}\right) - A\,\frac{e}{a} \dots\dots\dots\dots\dots\dots\dots\dots (7b)$$

It will be noticed, by reference to the foregoing figures, that if the connection between the top of the column and the superstructure be such as to hold the top in a horizontal position under the application of H, the effect will be to produce a negative moment in the column above X_1, and to increase the horizontal forces at the top and at X_1, without, however, affecting the bending in the column from the point X_1 to the base. Care should be taken, therefore, in designing the details of this connection, to have the vertical load come upon the column centrally and remain so, as the column bends slightly under the horizontal load. This is often not feasible, and in these cases the forces for connections, etc., should be determined by Formulas (6*b*) for the top and (7*b*) for the point X_1, and then increased somewhat to provide for the effect of the column top being connected rigidly to the superstructure.

Below the point X_1, the web of the column and the rivets connecting it to the flanges must be designed for a horizontal shear, of amount

$$H \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (8)$$

The base of the column should be designed so that it can receive, on one edge, without injury, a force of

$$P + A \dots\dots\dots\dots\dots\dots\dots\dots\dots (9)$$

and provision should be made for distributing this load on the masonry symmetrically about the corner of the column as the center of pressure, without exceeding the allowable limits of pressure on the masonry. With this in view, it is well to use a thick casting under the column proper.

The stresses in the column having been thus determined, it now becomes necessary to design the pedestal. The amount, direction, and point of application of all forces acting upon the pedestal are shown in Fig. 6, where P, A and H are the forces already determined, and W is the weight of the pedestal itself. It will be assumed that the pedestal rests upon a foundation of earth, on which the maximum permissible pressure per unit of area is p. Considering now the section $R\ S$ of the foundation, at the bottom of the pedestal, it must sustain a compressive load of $P + W$, uniformly distributed over its

surface, and a moment taken about its center, of section Y_1, equal in amount to

$$Mf = Hf + Pd + Ae \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

without exceeding the pressure, p, at the extreme leeward edge, R, and without tension at the opposite edge, S.

The base of the pedestal is assumed to be rectangular in section, of the dimensions shown, and symmetrical about the center of the column. Considering now the section $R\ S$, the reactions produced by the forces indicated are a uniformly distributed force, of value p_1 per unit of area, equal to

$$\frac{P + W}{g\ h} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

and a distributed force per unit of area, varying uniformly from a maximum of p_2, acting upward at the leeward edge, R, to an equal value of p_2 acting downward at the windward edge, S; the maximum value, p_2, of this force, per unit of area, being

$$Mf\left(\frac{6}{h\ g^2}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

To ensure a pressure on the foundation at the base of the pedestal not exceeding p on the outer edge, R, the value of $p_1 + p_2$ must be equal to or less than p; and to ensure there being no tension on the windward edge, S, the value of p_1 must be equal to or greater than p_2.

It will be noticed, by comparing Formulas (4) and (10), that increasing the force, A, acts against H, to diminish the total bending on the column, and with H, to increase the overturning on the pedestal. Increasing the value of d produces the same effect. In assuming the size of the anchor bolts and the width of the column, therefore, the relative cost of the column and the pedestal should be taken into consideration, with a view to maximum economy.

The value of P used should be the net value; for example, in a mill-building column it should be the total dead load coming on top of the column, plus the vertical reaction from wind for the leeward column, and minus that reaction for the windward column; in which case the total horizontal wind force coming on the building should be divided between the two columns, so that the combined stress from direct compression and bending will be the same for each column.

In Fig. 1a is shown in outline a modification of the general case under consideration. In this case a bracket takes the place of the

knee-brace or strut of Fig. 1, and Figs. 2*a*, 3*a*, 4*a* and 5*a* show, as before, the induced forces necessary for equilibrium, corresponding to those shown for the first case in Figs. 2, 3, 4 and 5. In this case there is substituted, for the single horizontal force applied at X_1, a force extending over the distance a, and varying in value uniformly from 0 at the top of the column to a maximum of h_o at X_1.

The moment of the external forces, taken about any point on the neutral axis of the column, distant x above the point X_1, and making $c_1 = d$, as before, will be (see Fig. 5*a*)

$$M = -H(b+x) + Pd + Ae + \frac{h_0 x^2}{2} - \left[\frac{x^2}{6}\left(h_0 - \frac{h_0 x}{a}\right)\right] \ldots\ldots\ldots (4b)$$

And this will be a maximum when $\frac{dM}{dx} = 0$; from which the value of x_2, the distance of the point of maximum bending above the point, X_1, is found to be

$$x_2 = \sqrt{\frac{4a^2}{9} + \frac{2Ha}{h_o}} - \frac{2}{3}a \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

and the moment at this point will be

$$M_2 = -H(b+x_2) + Pd + Ae + \frac{h_0 x_2^2}{2} - \left[\frac{x_2^2}{6}\left(h_0 - \frac{h_0 x}{a}\right)\right] \ldots (4c)$$

The connection at the top of the column must provide for a horizontal force of value H_0, and the bracket must be designed to withstand a force per unit of length varying uniformly from 0 at the top to h_0 at the distance a down from the top.

The observations on the effect of shifting the point of application of the load, P, on the top of the column, in the first case, apply similarly to the present case.

The point of contraflexure will be at the same location as before, and the masonry pedestal will also be the same as in the first case.

In the foregoing, the writer has not attempted to treat the subject under consideration exhaustively, but has confined his attention to the conditions which generally exist in the actual designing of columns of this class. No account has been taken of refinements which would not affect the final structure appreciably, and he has endeavored to deduce formulas which may be used as given herein by substituting the proper values of the forces and dimensions, when the loads are applied as indicated, or which, by a similar analysis, may be modified to suit the changes which may be necessary for any particular case.

Vol. XXVIII. MARCH, 1902. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

SOME DEVICES FOR INCREASING THE ACCURACY OR RAPIDITY OF SURVEYING OPERATIONS.

Discussion.*

By Messrs. Gerard H. Matthes, C. A. Sundstrom, John F. Hayford, William D. Lockwood, L. C. Sabin, Oscar Erlandsen, George A. Taber and Horace Andrews.

Mr. Matthes. Gerard H. Matthes, Assoc. M. Am. Soc. C. E. (by letter).—Professor Webb's efforts are a step in the right direction, and are characteristic of the tendency that has manifested itself of late years to simplify instruments and methods of surveying in order to lighten and dispatch work, and, at the same time, maintain a standard of precision sufficient for the purposes in hand. During the last two decades an enormous advance has been made in the construction of surveying instruments.

In the year 1870 the Great Trigonometric Survey of British India was still laboring with 36-in. theodolites weighing 370 lbs. when mounted, and as much as 1 050 lbs. when packed for shipment, inclusive of accessories. The present generation of surveyors may well consider themselves fortunate to be able to look back upon these ponderous machines as interesting relics of days gone by. Thanks to the

* This discussion (of the paper by Walter Loring Webb, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for December, 1901), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

Communications on this subject received prior to April 25th, 1902, will be printed subsequently.

modern dividing engine and to improved machine tools it is now possible to turn out theodolites with smaller plates graduated more accurately than the old hand-divided 36-in. circles. Mr. Matthes.

In this country the United States Coast and Geodetic Survey is using 12-in. theodolites for work of the highest order, while the United States Geological Survey finds that 8-in. theodolites answer its requirements. In mine surveying and in other fields, such as base-measuring and plane-table work, similar wonderful advances have been made, simpler and better forms of instruments taking the place of the old, complicated and cumbersome types.

Much remains to be accomplished, however. Many surveying instruments are yet far from being all that is desired, as regards fitness for the work for which they are intended. Their development is a process of evolution. The demand at the present day is not so much for the invention of new forms of instruments as for the perfection of those now in use. It is difficult to design any instrument of precision, with a complication of parts, and capable of delicate adjustments, that shall, at the same time, be easily manipulated, compact, readily transported, and strong enough to withstand the strains imposed upon it by rough handling and by sudden variations of temperature and humidity, which will not be thrown out of adjustment continually. Yet this is precisely what is desired of surveying instruments. Only through long use and experience can the best types be evolved.

Having had experience with instruments of different kinds, under a variety of conditions, from the intense heat of southern Arizona to the cold temperatures of northern Montana, the writer has been in a position to gain a full knowledge of the weak points in modern surveying instruments and the difficulties to be overcome in remedying them. It is therefore with joy that he hails the improvements suggested by Professor Webb, albeit some of his devices are capable of further improvement.

The shortening of the vertical arc on transits by the addition of a vernier seems to be an excellent expedient. The change is a decided benefit, while the extra vernier is in no sense a burdensome feature, and would tend to obviate errors in reading plus or minus angles, provided, of course, that the numbering on the arc and the verniers be made so as to easily distinguish plus angles from minus angles. This can be accomplished by slanting the numbers, as is frequently done on transit plates, which are numbered both ways. The question arises, however: If, according to Professor Webb's views, an arc of 60° amplitude is safe as regards injury, why not cut the ordinary form of arc down to that limit, thus leaving 30° on each side of the zero mark, and retaining only one vernier? Excepting instruments used in solar observations, where the long arc is a necessity, an arc of this amplitude would answer for all ordinary surveying operations. In the steepest

Mr. Matthes. hillside work stadia angles never exceed 30°, and anyone who takes stadia angles exceeding 25° is doing an inferior quality of work, at best, unless the distances are very short. The writer, therefore, would suggest that for transits not provided with solar attachments, or intended for special lines of work entailing the measurement of large vertical angles, an arc of 60° amplitude graduated after the common pattern is fully sufficient, and that, therefore, the author's device seems to be valuable for only such instruments as require long arcs.

Professor Webb's adjustable vernier attachment is a useful addition, particularly as regards its application to tachymeters. Obviously, the addition of an extra spirit level is no burden to a transit. In the case of the alidade, however, it must be thus regarded. It should be borne in mind that the plane table and alidade, considered as one instrument, is essentially used for mapping and reconnaissance purposes. This implies that it must be especially adapted to work in regions away from centers of civilization, where means of transportation are limited and rough. In other words, the table as well as the alidade should be made durable and strong, with as few parts requiring adjustment as possible, and yet, withal, be compact and light. In such an instrument every delicate part is a constant source of worry to the topographer during the journey or the march, and those who can speak from experience will not welcome additional level vials.

In the work of the United States Geological Survey, particularly in the Western States, the hard usage to which alidades are put is worthy of more than passing comment. In open terrain the topographer moves from point to point in a buckboard, and the jolting of these vehicles over prairies of bunchgrass pitted with badger and prairie-dog holes, or over a sagebrush country, can be understood only by those who have had the experience. In rugged country, recourse must be had to saddle and pack horses, and for hours the topographer may be required to trot over narrow trails, through timber and brush, while the pack animal behind him scrapes his precious burden through the best he can, the boxes or tripod frequently receiving hard knocks against tree trunks or projecting ledges; knocks which are unavoidable, and compared with which the jolting of the load due to the animal's gait is not worth considering. In addition, the topographer may have to ford mountain torrents time and again during the course of a day, and take chances of wetting his outfit. In ascending high peaks, even the faithful pack animal must be dispensed with, the topographer and his assistant dividing the instrument outfit between them, and carrying it up the mountain on their backs. Starting at 6 A. M., for instance, they may reach the top at 10 A. M. About four hours remain in which to do all the work, if another ascension of the peak is to be avoided. As a rule, the work averages from 40 to 80

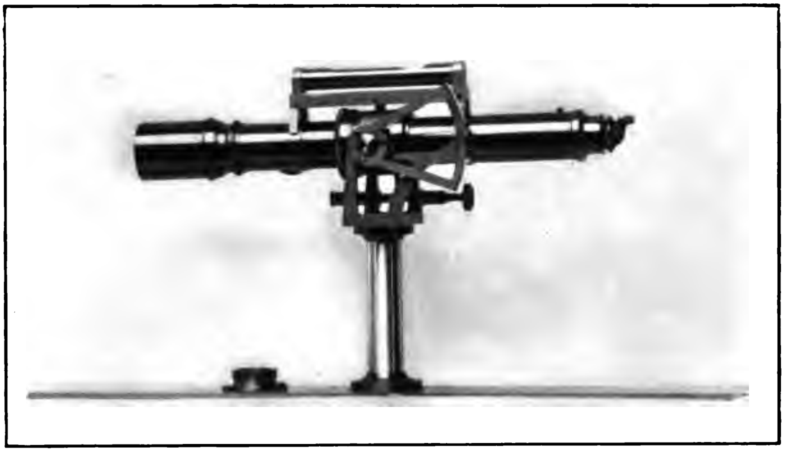


FIG. 1.—U. S. GEOLOGICAL SURVEY ALIDADE.

FIG. 2.—U. S. COAST AND GEODETIC SURVEY ALIDADE.

observations or more, and must be done rapidly if any time be left Mr. Matthes.
for luncheon and for sketching. Consequently, it is important that the alidade should come out of its box none the worse for the rough usage it has received in transportation, and its adjustments must be few and rapidly disposed of, so that in a few moments it will be capable of doing first-class work. On the way down the mountain the topographer, carrying the alidade box on his back, may have to jump down a dozen or more ledges 5 or 6 ft. high, and similar jumps may have to be made in working through "down timber."

The foregoing is no exaggeration of facts. Scores of men are annually engaged on surveys where that is the daily routine, and the alidade must be proof against rough handling, or it is not fit for the work.

Regarding the form of instrument used, the United States Geological Survey sends out during each field season an average of 120 plane-table parties equipped with telescopic alidades, the great majority being of the type shown in Fig. 1, Plate XIV. The work of these parties is in all parts of the United States, Alaska, and the insular possessions; in other words, it comprises all forms of topography and climatic conditions. The United States Coast and Geodetic Survey likewise has annually from 25 to 30 plane-table parties in the field, covering the same range of territory and using an alidade of practically the same construction as that shown in Fig. 2, Plate XIV. These are significant facts. Here are two scientific bureaus, independently of each other, pursuing work of a similar character. Through the experience gained during past years, not by a few, but by hundreds of topographers belonging to both Surveys, each bureau has evolved a type of alidade which seems to give the best satisfaction for its particular work, and a comparison proves that the instruments are essentially alike, the principal difference being that the Coast Survey alidade is provided with a filar micrometer eye-piece, while that of the Geological Survey has either a plain or a prismatic eye-piece. These types of alidade have not been selected arbitrarily. Suggestions for improvements have been innumerable, and many of them have been given a practical trial. The present form of Government alidade has stood the test of years, and it may safely be predicted that nothing short of a radical change is likely to modify it.

A comparison of this alidade with Professor Webb's (Plate XXII, Fig. 1*), becomes of interest. The most prominent difference, probably, is in the vertical arcs. It seems unfortunate that Professor Webb has selected, for the purpose of illustrating his attachment, an alidade provided with the old-fashioned arc, which requires the topographer to step aside at each reading. The arc adopted by the Government bureaus mentioned bears the graduations on the rim, that on

* *Proceedings*, Am. Soc. C. E., December, 1901.

Mr. Matthes. the Coast Survey alidade being slightly beveled, and is adjusted so as to be easily read from the eye-piece end of the telescope; in short, it enables the topographer to read his angles without moving his position.

This is a feature of importance, for it not only saves him from stepping around the table, but frequently the table must be mounted on narrow projecting ledges where one side only of the instrument can be approached, and in such cases it is always possible to read the angle, even in difficult positions, as long as the eye can reach the eye-piece. A further advantage accrues from the fact that this form of arc permits a shortening of the Y's and a corresponding lengthening of the standard, a feature of prime importance in the rapid and safe handling of the instrument. A glance at the alidade on Plate XXII, Fig. 1, will convince one that not only is the standard awkwardly short, but the vertical arc and its bubble attachment are precisely where they are most likely to be injured, being alongside the part of the instrument which has to be handled most.

Professor Webb's adjustable vernier principle could just as readily be applied to the form of alidade shown in Fig. 1, Plate XIV, and would there be in a much safer position.

The next and most important point of difference between the two forms of alidade lies in the method of reading the angle. The Government alidade has an arc, the graduations of which are entirely arbitrary as regards point of reference. Frequently, no zero point appears on the limb. Angles are read by subtracting the readings obtained with telescope inclined and telescope level, and, as will readily be seen, the topographer has no temptation to read an angle and neglect to correct it for inclination of the table. Numerous devices have been experimented with to obviate the necessity of reading the limb twice, and leveling the telescope after each pointing. The author's device is one of a great many, and is by no means new. Kern and Company, of Switzerland, who rank among the foremost instrument makers of the continent, have for years manufactured an alidade with an adjustable vernier almost exactly like that of the author. The principal advantages gained by this feature are: (1) The arc need be read but once; and (2), no angles need be subtracted. Thus time is saved in two ways The objections are: (1) As stated before, an additional spirit level is required; and (2) the accuracy of the entire operation depends upon the assumption that the vernier reads zero when its level is parallel with the striding level and the latter with the line of collimation.

In the writer's opinion, such a combination of conditions will require frequent testing of the adjustments, especially on hard trips. Besides, the adjustments involved number four (against two in the Government alidade), and one of them, *i. e.*, making two spirit levels

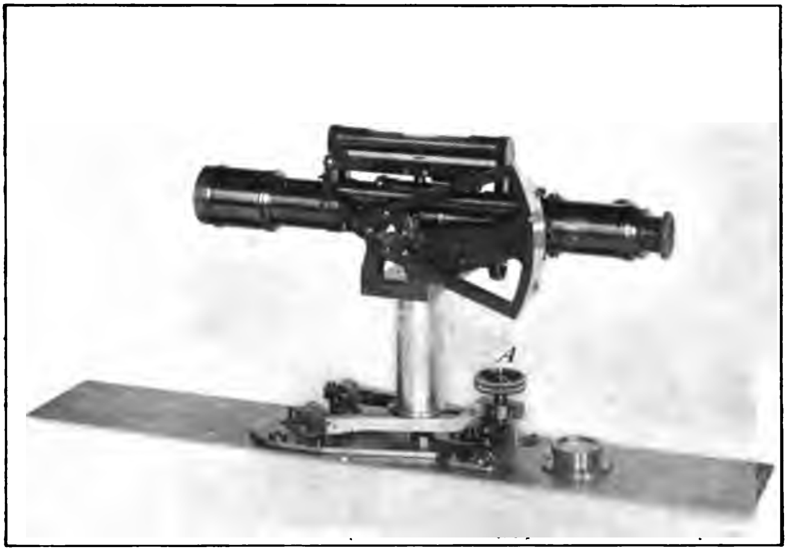


FIG. 1.—THE BUMSTEAD ALIDADE.

FIG. 2.—THE TACHYGRAPHOMETER.

parallel with each other, is a feat which even the author would probably hesitate to undertake when pressed for time, on top of a peak, assuming even a moderate wind to be blowing. The chances are that the average topographer would trust to the adjustment being correct, and proceed with his work, to the detriment of its accuracy. After all, in a practical consideration of the time actually saved by means of this device, it is found to be disappointingly small. Mr. Matthes.

As regards doing away with the subtracting of angles, no time is actually saved, for the recorder has ample time on his hands in which to dispose of such computations, and check them besides. Doubtless, it would greatly lighten his work, and, in this sense, would be valuable, but no time would be saved by it as regards carrying on the survey. In this method, as in the other, a bubble must be brought to the center of its tube; and there remains, therefore, as actual net saving, the time required to read the vernier once. The question naturally arises: Is this saving of time commensurate with the addition of an extra spirit level? Evidently not; unless, perhaps, the alidade is to be used for detailed stadia surveys in centers of civilization, as, for instance, on plans for landscape architecture, where the means of transportation may warrant the use of elaborate instruments. Here, no doubt, the author's alidade will be found a most serviceable instrument.

A brief description of some of the best forms of alidades in use will be of particular interest in this connection. The Government alidade has only two adjustments, both of which can be instantly tested whenever the topographer has reason to suspect anything wrong; and the adjustments themselves are so simple that they can be disposed of in a very short time, varying, of course, with the skill of the topographer and the velocity of the wind. The first is the adjustment of the striding level, which is attained in the usual manner, by reversing it, end for end. The second is the collimation adjustment, the horizontal wire only being corrected. For this purpose, the telescope has been fitted in a sleeve provided with stops which allow it to be turned 180° about its optical axis. The latest forms have a reticule held by four capstan-headed screws which can be moved in any direction. An error in the position of the vertical wire, however, will have no effect on the work, provided it is constant during any one set-up. The same is true of any lack of parallelism between the edge of the ruler and the line of collimation. The horizontal axis of the telescope is adjusted by the instrument-maker as accurately as possible, and no provision is made for further adjustment. The limb is graduated to 30′, the vernier reading to single minutes. Most alidades are provided with a declinatoire fastened to the ruler, as shown in Fig. 2, Plate XIV. In some classes of work a prismatic eye-piece is indispensable. When provided, as shown in the illustration, it should be made removable. To level the table a circular bubble attached to the

Mr. Matthes. ruler has been found to be the simplest and best device. The United States Coast and Geodetic Survey alidade is provided with a filar micrometer eye-piece, which enables the topographer to determine the distance to a triangulation signal by measuring the fraction of his cross-wire interval subtended by a known distance on the signal, a valuable aid in a country where triangulation signals can be built of wood. It is particularly useful in taking long sights, exceeding the limit of stadia observations, where no great accuracy is required, as, for instance, in plotting wood or marsh lines. A two-target rod is used in such cases.

Simple as it is, the Government alidade is entirely adequate for the work, and the very highest grade of topographic surveying is daily being done with it. On the whole, it may be said that it is much easier to design surveying instruments with a complication of parts, than it is to design those of simple and yet adequate construction.

It is gratifying and worthy of note that in this respect American instrument makers are ahead of European makers. Many types of surveying instruments manufactured abroad at the present day, referring to those of the best makers, are provided with parts, which, to the practical engineer in this country, are mere elaborations, and are frequently more of a hindrance than a help. Generally, many such parts, though useful, can be dispensed with altogether, by adopting different though equally good methods of prosecuting the work; or they could be replaced by simpler devices, which would reduce the weight of the instrument, increase its portability and necessitate fewer adjustments.

The error most frequently made is that of endeavoring to produce instruments that shall be capable of a multitude of operations, perhaps going to the extent of solving formulas, an endeavor which in itself is commendable enough, having as a primary object the saving of time, but which in its practical application is likely to result in the instruments produced being so bulky, so unnecessarily complicated, and consequently so hard to keep in adjustment as to defeat the very object for which they were designed. As a conspicuous example of misdirected efforts of this kind the Tachygraphometer, shown in Fig. 2, Plate XV, and which will presently be described, is noteworthy.

Among the great variety of existing forms of alidades, two are found which merit attention, being particularly designed to "increase the accuracy or rapidity of surveying operations." The Kern alidade, mentioned previously, is provided with a complete vertical circle graduated on its rim, with an adjustable vernier and spirit level, and with an attached reading glass. The telescope is mounted on one side of the standard, and can be completely revolved about its horizontal axis, its weight being counterbalanced on the other side of the standard by the vertical arc and its accessories. In addition, the standard can

be fastened at several points along the ruler, a great advantage in working with a large table. The Kern alidade is a beautifully finished instrument, and its scarcity in this country must be accounted for by its elaborate character, which renders it wholly unfit for hard service. Mr. Matthes.

Another form of alidade which unites many practical advantages is that invented by Mr. A. H. Bumstead, of the United States Geological Survey, shown in Fig. I, Plate XV, and manufactured for him by W. and L. E. Gurley and Company. As in the Kern alidade, its standard is detachable, and can be mounted rigidly and with ease, by means of an ingenious device on rulers of different lengths, carried by the topographer in a special case. The vertical arc is similar in form to that of the Government alidade, but is graduated 30° each way from the zero point, which is in the center of the limb. A spirit level, not easily distinguished in the illustration, being partially hidden by the vertical arc, is attached, by means of a stout projecting arm, to the standard, making it possible to level the entire instrument frame, exclusive of the ruler, by turning the screw *A*.

The adjustments are made as follows: The striding level is first made parallel with the line of collimation, as in other alidades; the vernier is then set at zero, and the entire instrument is leveled by means of the striding level and the screw *A*. This accomplished, the spirit level mounted on the standard is made parallel with the striding level, after which the striding level can be removed, and the alidade is ready for work.

The operation of reading a vertical angle is as follows: The telescope is pointed at the object to be located, and the bubble is brought to the center of its tube. The telescope is then clamped, and the horizontal wire is brought to the desired height on the object or rod, and the true vertical angle can then be read at once.

This alidade possesses another valuable feature, With the aid of a horizontal screw to the right of *A*, but not visible in the illustration, the entire instrument frame can be rotated in azimuth on the ruler. The object of this attachment is to enable the topographer, when first orienting the table, to bring the vertical wire exactly on the triangulation signal sighted, after he has brought it approximately there by setting and clamping the table. Mr. Bumstead's alidade has also been made with a filar micrometer eye-piece, intended to be used for the same purpose as in the case of the Coast Survey alidade. The former instrument has been used during the last two years by its inventor and others on the survey of the Adirondack Reserve, and has given excellent satisfaction. In the writer's opinion, the field for the above described forms of alidade, including that of the author, will necessarily remain limited, owing to the fact that their constructions are not adapted to rough means of transportation.

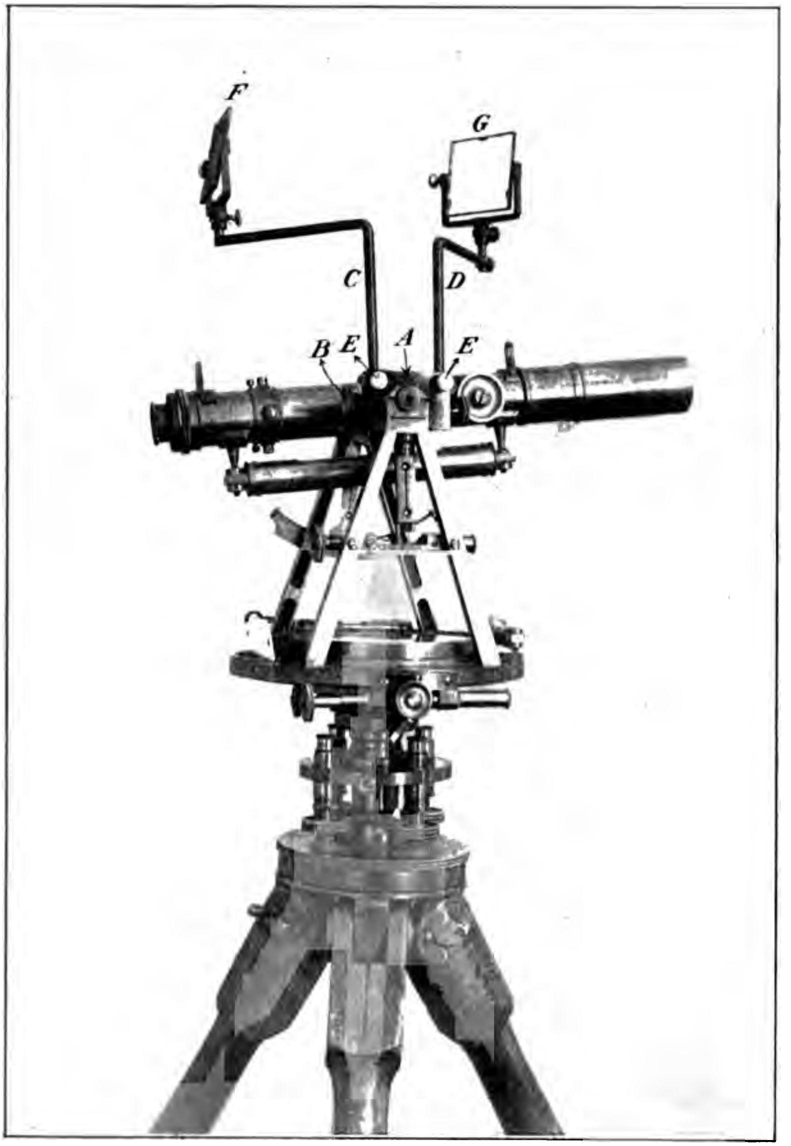
The Tachygraphometer, shown in Fig. 2, Plate XV, is manufactured

Mr. Matthes. by L. Tesdorpf, of Stuttgart, Germany. It is designed to take the place of the alidade on the plane table, and purports to reduce and plat stadia observations mechanically. Being mounted on three ivory wheels, its position on the table can be shifted at will, small brakes being applied when the instrument is properly pointed. The telescope once set and the rod reading taken, the operator, for he can hardly be called a surveyor, sets the index of a scale opposite the proper rod reading, and without further bothering his head about vertical angles, proceeds to shift a series of parts, when lo! the elevation of the point sought is indicated on the vertical scale, and the location of the point itself is correctly brought about by merely pressing a button. Had only a nickel-in-the-slot attachment been provided, could anything more perfect be imagined? But let not the reader enthuse too soon. The operator has completed his set-up and is about to move to another point. He takes the Tachygraphometer from the table, but finds he cannot carry it like an alidade, for not only is it too heavy, but it affords no convenient hold anywhere. He must put it back into its box. More trouble! The instrument will not go in as it is; some of its parts must first be removed. These fit in the box in places specially provided, and not until they have been taken care of can the instrument itself go in. The box is ready at last, and a right heavy load it is. The topographer picks up his table, the assistant with the Tachygraphometer comes toiling after, and by the time they reach the next station, they will probably find their patient rodman slumbering peacefully. The stadia rod used in conjunction with the Tachygraphometer is held at right angles to the line of sight, the rodman being provided for this purpose with a simple wooden attachment serving as pointers. In keeping with the complicated character of the instrument, the graduations of the rod are of a complexity that defies description.

The writer has had occasion to test the Tachygraphometer. It did splendidly, but fortunately he did not take it further from the house than the adjoining tennis court. Only one instance of this instrument being used on actual surveys on this side of the Atlantic is known to the writer. This was on a railroad survey in Mexico, during the course of which it soon developed that the Tachygraphometer was least of a nuisance when left at the office. If other surveyors have had a profitable experience with this instrument the writer would be glad to be informed. The Tachygraphometer is a beautiful mathematical machine, but, as a surveying instrument intended to lighten and dispatch work, it is a failure.

Mr. Sundstrom. C. A. Sundstrom, M. Am. Soc. C. E. (by letter).—Mr. Webb's devices no doubt increase the accuracy of the work, but some of them introduce great refinement, where only approximate results can be obtained, and, by increasing the number of appurtenances to the instruments, make them unnecessarily bulky and heavy.

PLATE XVI.
PAPERS AM. SOC. C. E.
MARCH, 1902.
SUNDSTROM ON SURVEYING INSTRUMENTS.



HELIOTROPE ATTACHMENT FOR A TRANSIT.

As the plane-table alidade, the first instrument mentioned by Mr. Webb, must be used in conjunction with the plane table, a short review will be made of the uses for which the plane table is adapted. Mr. Sundstrom.

The main object of all surveying instruments is to determine the geographical location and shape of tracts of land or objects on the surface of the earth. The principal outlines of a tract of land cannot be determined accurately by means of a plane table. They must be located geodetically or trigonometrically. But the interior part, or the filling in, can be accomplished by the use of the plane table. The location of houses and other objects on the surface of the earth can be made very advantageously by the method of intersections, when the alidade without telescope can be used. For the location of contours, a more complicated alidade can be made useful. In the writer's opinion, leveling with the alidade is not practicable. The best results are obtained by using an engineer's level for getting elevations, and using the alidade only for determining geographical positions. The alidade will then be reduced to the smallest number of parts, and thus become light and convenient to handle. A light alidade will not be so apt to throw the plane table out of line as a larger and heavier instrument would.

The writer was employed by the Swedish Government on topographical work about 24 years ago. On this survey, all the instruments were extremely light and convenient to handle, with the exception probably of the theodolite used on the triangulation. The plane table was made in the form of a box, 14 x 12 x 1½ ins. The bottom and sides were made of hard wood, beech or birch, and the top of white pine or aspen. One longitudinal and one transverse rib added strength to the table. The thickness of the wood was ¼ in. The top was made of soft wood, so that a needle could be used to determine the point about which the alidade was to revolve; and, in order to secure the exact position of the alidade along important sight lines, a needle was placed near the edge of the table, at each terminus of the line. The appurtenances to the plane table consisted of two alidades (one with and the other without a telescope), one spirit-level, one compass and one plumb-bob, all placed in a light box, which the rodman carried on his back by a strap. The alidade, with the telescope, weighed less than 3 lbs. The telescope was ¾ in. in diameter, and was fastened to the side of a hollow cylindrical post, attached to a ruler, 12 ins. long and 1½ ins. wide, beveled on one edge, and channeled on the under side. The telescope was provided with a level, a vertical arc and stadia wires. The paper used for the plane table was 14 x 16 ins., and was stretched on the table in the following manner: The four corners were cut off, the cuts making right-angled triangles of about 1 in. base and altitude, each hypothenuse being

Mr. Sundstrom. perpendicular to the diagonal through the corner. The paper was then wetted, and, after glue had been applied to the sides of the plane table, the overhanging edges of the paper were turned down and glued to the sides of the table. When the table was nearly covered by parts of a map, an extra table, with the paper stretched on it, was carried in the field, and upon it the work was continued. When more than one extra table was used, a light box containing them was carried along.

The nearest approach to Swedish plane tables, which the writer has seen in this country, are those used by the United States Geological Survey, and are 15 ins. square.

The use of the stadia slide rule is not so convenient as the graphical chart. Such a chart, made of the same size as the plane table, can easily be placed on top of the table, and held there by the covering used for the protection of the table, while the instrument is moved from one station to another. The chart has another advantage in enabling one man to attend to the plane table, without losing time. As soon as the stadia reading has been made, the plane-table man has ample time to make his reduction by the chart, and plot the point on the table, while the rodman moves to another station and the leveler to a new point. A self-reading level rod was used, both for leveling and stadia readings.

The tension frames for steel-tape measurements are not practical. No doubt, they work well in measuring a base line on the university campus, but they are useless in hilly country. Professor Jäderin's arrangement* is far better.

Before leaving this subject, the writer would like to call attention to some devices which he has found useful during many years' practical experience in surveying. One of the most useful is the etched cross-hair, made by photographing a cross on a thin piece of plate glass, large enough to be placed in the metal ring which usually carries the cross-hairs. After the negative is obtained, it is exposed to the fumes of hydrofluoric acid, until an etching sufficiently deep has been produced. In order to make the cross opaque, blacking can be placed in the etching, which makes the cross more clearly visible when strong light enters the objective of the telescope.

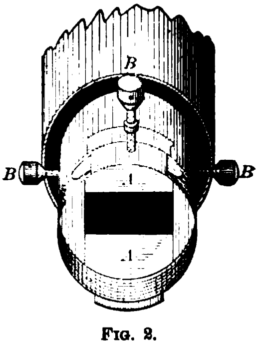


FIG. 2.

The glass-edged stadia are made from two pieces of plate glass, attached to a metal frame, as shown in Fig. 2. The pieces of plate glass, *A A*, are adjusted by the capstan screws, *B B*, which operate the metal frames into which the glasses are inserted. The glasses have their

* See Johnson's "Theory and Practice of Surveying."

inner edges slightly beveled and highly polished, and, after having been properly adjusted, the beveled edges will serve as stadia wires. An arrangement is also made, by which the glass-edged stadia are out of focus when the cross-hairs are visible, and *vice versa*. A transit with etched cross-hairs and glass-edged stadia has been in use by the writer for two years, and, although tested frequently, there has been no necessity for adjustment in that time. Mr. Sundstrom.

The heliotrope attachment to a transit is shown on Plate XVI. *A* is a clamp attached to one of the standards of the transit, and is held in position by the screw, *B*. Two bent standards, *C* and *D*, are inserted in the clamp, *A*, and secured by the screws, *E E*. Each of the standards carries a mirror with two motions, and, by revolving the standards and moving the mirrors, a flash in the direction of the line of collimation of the transit can always be produced in every position of the sun.

JOHN F. HAYFORD, ASSOC. M. AM. SOC C. E. (by letter).—In the fifth portion of Professor Webb's paper it is set forth rather tersely that to satisfy the requirements of modern steel-tape measurements it is necessary to determine the tension on the tape with great accuracy; that the tension must be determined "with an accuracy which is beyond question"; that the ordinary spring balance is useless for this purpose, and that even if a high-grade spring balance is used there is an uncertainty as to the tension actually measured when the balance is used in the horizontal position, which, added "to the feeling of uncertainty of the measurement of a force by a spring" makes the spring balance unfit for use in connection with precise steel-tape measurements. An apparatus designed by Professor Webb for putting the tension on a steel tape and measuring it by the moment of a weight about a knife-edge is then described fully. Mr. Hayford.

The writer does not believe that the facts warrant such a summary dismissal of the spring balance from consideration. It has proved its usefulness and reliability on twelve primary bases in the Coast and Geodetic Survey, and has remained and still remains in use and in good favor after ten years of service. During all these years the spring balance and its mounting, as used by Professor R. S. Woodward on the Holton Base,* has remained practically unmodified. It will be difficult to find in the United States any other stretching device for tapes which has been subjected to a test which is comparable with that through which this one has passed so successfully.

The writer believes that the method of measuring the tension on a tape which is advocated by Professor Webb—and it has been advocated by others—has a possible field of its own. To adapt the device for actual field use, rather radical changes in the design here submitted would seem to be necessary, however.

* See Coast and Geodetic Survey Report for 1892, Appendix No. 8, pp. 414–415.

Mr. Hayford. In the following paragraphs an attempt will be made first to indicate briefly the superiority, under certain conditions, of the spring balance over the gravity balance for the measurement of tape tension; and secondly to indicate the possible field within which the gravity balance is to be preferred to the spring balance.

The spring balance used by the Coast and Geodetic Survey in its primary base measurement carries a dial graduated to 25-gr. spaces. Under field conditions there is found to be no difficulty in holding the pointer to within 12 gr. (0.4 oz.) of a given reading. This spring balance is hung in gimbals at its center of gravity (after counterweighting). The gimbals are supported in position by a lever about 4 ft. long used in a nearly vertical position and having its lower end connected by a universal joint to a heavy foot-board laid flat upon the ground, and upon which the operator stands. The gimbals and balance can be adjusted quickly to any desired height within a total range of about 2 ft. by a heavy nut moving on a screw thread cut on the lever. With this apparatus an experienced operator requires very few seconds, after reaching a new station, to get his balance adjusted to the proper height and position and to apply the desired tension. Neither does he find any difficulty in maintaining the desired tension continuously within 12 gr., even at the end of two or three hours of continuous tape measurement during which he has walked and carried his apparatus several miles, and set it up at scores of different points.

All accurate field tape measurements, in so far as the writer is aware, are made with the tape supported at a few points only. Under these conditions the distance between the end graduations of the tape increases with an increase of applied tension, both because the tape stretches by an amount which is dependent upon its modulus of elasticity, and because the sag of each catenary formed by the tape is decreased.

The primary-base tapes now used in the Coast and Geodetic Survey are of steel, about 6 mm. ($\frac{1}{4}$ in.) wide and 0.5 mm. ($\frac{1}{50}$ in.) thick, and weigh about 22 gr. per meter of length. When in use they are supported at intervals of 25 m. The tension applied is 15 kgr. A variation of 12 gr. (0.4 oz.) in either direction from the tension of 15 kgr. makes a change of only 1 part in 3 000 000 in the apparent length of the tape. As previously stated, the tension is easily held within this limit on each tape length. The small outstanding accidental variations from the standard tension, due to variations within this limit, and to friction in the apparatus, necessarily have a decided tendency to be eliminated by compensation in the long run. All difficulty about the difference between the inclinations of the balance in the horizontal and the vertical positions is avoided, in the practice of the Coast and Geodetic Survey, by standardizing the balance in the horizontal position. One of several spring balances is carefully standardized

at the beginning and end of the working season. During the working Mr. Hayford. season the balance which is actually used on each night of base measurement is compared with this standard just before starting away from camp. The same man operates the spring balance throughout the season, during the standardization of the tape as well as during the base measurement. As what is really necessary to secure accurate results is that the tension applied to the tape during base measurement shall be exactly the same as that applied to it during standardization, it is believed that the practice outlined above insures that the constant error in any base due to error in applied tension is surely less than 1 part in 1 000 000.

In the primary-base measurements of the Coast and Geodetic Survey the device for applying the tension at the rear end of the tape is simply a light crowbar. The man with the bar comes up to his new position when the tape is carried forward, strikes the bar into the ground at the proper point, which he estimates with sufficient accuracy by eye, slides the loop of cord, around the bar to which the tape is fastened, upward or downward to the desired position, and by a backward movement of the upper end of the bar, using it as a lever, brings the graduation of the tape to exactly the correct alignment and longitudinal position. An officer with a small reading glass, kneeling at the rear-end stake, controls the final adjustment to exact coincidence between the tape graduation and the fine line on a copper strip on the stake which marks the previous position of the front-end graduation of the tape. He controls the man at the bar by word, and, at the same time, steadies the tape and eliminates slight longitudinal motions by pressing the tape lighly against the top of the stake with one finger. By this method there is found to be no difficulty in making a coincidence to within 0.1 mm. (or $\frac{1}{250}$ in.) in a few seconds.

No appreciable gain in accuracy in geodetic operations is gained by reducing the accidental errors of base measurement below the limit indicated by a probable error of 1 part in 500 000. Any greater accuracy is lost in the first group of triangles surrounding the base. If steel tapes are used with mercurial thermometers at night, there is no difficulty in rapidly securing as great a degree of accuracy as this. On the other hand, even if all possible precautions are used, the probable error can with difficulty, and only at considerable extra expense, be reduced below 1 part in 3 000 000 when mercurial thermometers are used, and great and perhaps insuperable obstacles are encountered in trying to insure that a constant error as great as 1 part in 1 000 000 is not left in the final result, due to the thermometers indicating an erroneous temperature for the tape. The writer believes that within this range of accuracy, of which the lower limit is fixed by the possible accuracy of triangulation and the upper limit is fixed by the defective indications of mercurial thermometers, the

Mr. Hayford. spring balance is to be preferred to a gravity balance as a tape stretcher, because it can be much more conveniently and quickly handled.

Professor Webb's gravity balance would be found to be very slow and inconvenient to handle in the field, because it has insufficient range of adjustment and very slow means of adjustment. The base tape must hang clear of the ground at all points. This makes it necessary to have a range of at least 2 ft. in the height of end stakes, to avoid much grading. There must be a corresponding range in height of adjustment of the stretching device, and the device must be capable of a quick adjustment over this whole range. Professor Webb's apparatus is decidedly faulty in this respect. A successful tension apparatus must have within itself a considerable range of longitudinal adjustment, otherwise much time will be lost in placing the supporting frame by trial in various positions, especially in stony or otherwise troublesome ground. Both the front and rear end tension frames in Professor Webb's apparatus are decidedly defective in these respects, in comparison with the Coast and Geodetic Survey apparatus. Moreover, in the use of Professor Webb's apparatus it is evident that the inclination and the alignment of the tension frame at the front end of the tape must be made nearly correct, as a comparatively small error in either of these respects will either throw the apparatus out of use or make the tension erroneous. The necessity of setting the front tension frame to conform with these requirements will help to make it a slow and annoying apparatus for field use. In the Coast and Geodetic Survey stretching apparatus these two adjustments are made automatically by the gimbals.

During the working season of six months in 1901 nine primary bases were measured by the Coast and Geodetic Survey by one party, under Mr. A. L Baldwin.* These nine bases are scattered along the ninety-eighth meridian from northern Nebraska to southern Texas. Their aggregate length was 69 km. (43 miles). The probable errors of these bases vary from 1 part in 690 000 to 1 part in 1 640 000. About four-fifths of these measurements were made with steel tapes, mercurial thermometers and the stretching apparatus referred to previously. About two-fifths of all these measurements were made with tapes only 50 m. long. The average speed of measurement with these 50-m. tapes for the whole season was 1.8 km. (1.1 miles) per hour, or thirty-six tape lengths per hour. On eight different occasions during the season measurements of from 1 to 3 km. were made at a speed exceeding 2 km. per hour. This corresponds to less than 90 seconds per tape length, including the walking and miscellaneous delays. The time spent, after reaching a new tape position, in stretching the tape, making the coincidence at the rear end, marking the position of the

* A complete account of these base measurements will appear in a few months in Appendix No. 3, of the Coast and Geodetic Survey Report for 1901.

front end, and reading the thermometers, was, therefore, during regular work, from 30 to 40 seconds, on an average, and, very frequently, must have been less than 20 seconds. If Professor Webb will try to manipulate his apparatus, even with an experienced party, at a speed even one-half as great as this over ordinary ground, he will understand why the Woodward tape stretchers are still in favor in the Coast and Geodetic Survey. Mr. Hayford.

If any method is put into use by which the temperature of the tape can be obtained accurately, and the limitation on the accuracy imposed by the use of mercurial thermometers is thus removed, it will become possible to measure a base with a steel tape with a probable error of 1 part in 5 000 000. When this is attempted it will be necessary to measure the tension with a considerably higher degree of accuracy than is attainable with the spring balances and stretching device now in use in the Coast and Geodetic Survey. The gravity balance may be the tension instrument of great accuracy which is needed for this purpose. But it is not at all certain, if equal care were taken in designing two sets of stretching apparatus for this special purpose, in one of which a gravity balance should be used and in the other a specially designed spring balance, that the spring balance would not be found to give as great accuracy as the gravity balance and still preserve its present superiority as to rapidity and convenience of handling. It should be kept in mind that the spring balance now used by the Coast and Geodetic Survey is of the ordinary type which can be bought in the market for $3.50, and it will not be difficult to improve upon its present construction. The writer would be pleased to see someone perfect the gravity balance for use as a tape stretcher on field measurements of the highest grade of accuracy. Professor Webb's design would be unsatisfactory for such use unless radically modified along the lines indicated by the preceding criticism, so as to make it capable of rapid handling.

In the preceding paragraph the possibility of a method of determining the tape temperature with the accuracy necessary to obtain a probable error of 1 part in 5 000 000 being put into use is mentioned. The thermophone apparatus, designed at the Massachusetts Institute of Technology,* furnishes, so far as the writer is aware, the only promise of immediate success in this respect. This apparatus measures directly the variation in the electric resistance of the tape, which is a function of the temperature of the tape.

WILLARD D. LOCKWOOD, Assoc. M. Am. Soc. C. E. (by letter).— Mr. Lockwood. This paper has brought forward some points that have been often discussed in the hearing of the writer during the past ten years, and which are probably familiar to most engineers who have had any very extended experience in the field.

* A description of this apparatus is published in the *Technology Quarterly*, June, 901, pages 82–88.

Mr. Lockwood. The writer agrees most cordially with Mr. Webb as to the use of the stadia in connection with the plane table, though the experience of the writer, with the plane table, is where it has been used as a means of cutting in controlling points, with the intermediate topography sketched in; but Mr. Webb evidently has reference to more detailed topography.

As to the accuracy of stadia work when the plate bubbles alone are to be depended upon, any intermediate point on such work, for a topographical map, is assuredly secured by the plate bubbles much within the limit of control of the shot in question. Take a shot of 1 000 ft.; of course, on a stadia survey there must of necessity be many such, as the great value of stadia work is in covering large areas from few set-ups. Now, in 1 000 ft., where the intermediate shots are being taken with great rapidity, the rod can be moved forward or back 1 ft., and the observer would seldom make a change in the reading, thus making a variation of 2 ft. in distance; now, suppose the ground to be very irregular, or a side-hill, then this 2 ft. could easily change the elevation 1 ft.; hence it is quite evident that a minute of arc in elevation is a small factor, as in 1 000 ft. it would amount to about 0.3 ft.; and the writer has observed that the horizontal corrections on the intermediate shots are seldom made when the angle is less than 4° (as it is evident that it would be useless refinement, from the fact that the contour to the next point is to be sketched in, and the uncorrected shot in question will be well within the limits of the work). This is all with the understanding that the survey is controlled by a transit, level and steel-tape base line, which the writer believes should always be the case where close map work is to be expected.

It would seem to the writer that the refinement suggested by Mr. Webb is rather unnecessary; past experience has shown that splendid results may be achieved by the regulation instruments, when the work is done with care by good men. In the report of D. J. Howell, M. Am. Soc. C. E., to the United States Board of Engineers on Deep Waterways, he states that with properly graduated rods and ordinary refined methods, the following results were obtained:

Forty-four circuits, selected at random from several months' work, as run between April and July, 1898, show

Average length of circuits..................	7 384 ft.
Average number of stations occupied.......	12
Average running error in azimuth...........	1′ 32″
Average error in elevation	0.35 ft.
Average error in circuit	1 in 1 832
Maximum error in circuit..................	1 in 760
Minimum error in circuit..................	1 in 4 244

Of course, these results speak for themselves.

As to the vertical arc on a transit, the writer has heard more hard names applied to a transit, and to the company who sent it, when it appeared on the work with an arc instead of a full circle, than to all the other cheap instruments and attachments ever sent out. And the adjustable vernier secured nearly as much abuse as the arc, and to the mind of the writer, justly so, as many mistakes have been made through the use of this form of attachment, it being doubtful what class of work a man would do with it who could not put an instrument away in the box, as Mr. Webb suggests, without bending the arc; such a man being just about as apt to knock the capstan heads off the diaphragm screws. Mr. Lockwood.

As a rule, when an engineer has a survey of magnitude to make, he finds there is but little money with which to make it, as the money comes later, when the project is decided by the survey. What he desires to get are plain men and plain instruments, both without attachments; not necessarily the much-vaunted "practical men," but the men of that class who have been so pertinently described as "men who can do things." The points of control for the map are first secured by using the combined strength and intelligence of his whole party; then the filling in can be done by any of the various methods, without a possibility of multiplying errors. These methods are used, it must be understood, when material for a first-class map is wanted, not for an elaborate, padded report.

As to the carrying of a transit through the bush, the writer has found that his associates always agreed that there was but one safe way, and that was with the telescope thrown up in line with the tripod, as when allowed to project it will indeed be a "sore finger," as Mr. Webb says of the arc. Of course, this position of the telescope, with an arc, is out of the question, and is one of the many reasons against the use of anything but a full circle.

In connection with the subject of "Aids to Field Operations," the writer would like to mention the hand-level, as one cannot be thoroughly familiar with the great value of this little instrument without having had extensive operations in a heavily wooded country. In the course of recent surveys made by the writer, under the Isthmian Canal Commission, in Nicaragua, the usefulness of the hand-level was shown up in all its details. In making a location for a part of the canal line, it became necessary to develop a large area of hilly country, the most densely wooded in the world, where nothing more than tunnels could be cut through the rank vegetation. A base line was run with transit, steel tape and wye-level, and then the topographers with their little hand-levels and cross-section books attacked the maze of tunnels and cross-tunnels, rarely seeing the sun from the time they left camp until their return. The writer believes that the method of cutting the map into small sheets and actually plotting the topography as it

Mr. Lockwood. is taken in the field, is much superior to, and fully as economical, as the use of note-books. In Nicaragua it was out of the question, owing to the constant rains, as the note-books by night were often as wet as though they had been dropped into a river, and, in fact, they occasionally were, along with the topographers.

The results of the hand-level topography were most gratifying, as a projection made on the map, from this survey, was staked out with precision, and checked a line through the work several miles long.

It has given the writer pleasure to see the details so well worked out in Mr. Webb's tension frame for steel-tape measurements, as the old devices, of which the writer has made use in the past, compare about as favorably as an old stage coach to a modern automobile. But, in making use of Mr. Webb's device, it would seem that more ease in manipulation could be secured by extending the graduated lever-arm forward, with a tip turned up at the end, to correspond in height to the tape clutch above the arm, thus readily showing when the tape is in perfect alignment, and also pulling absolutely at right angles to the short lever-arm.

Mr. Sabin. L. C. SABIN, Assoc. M. Am. Soc. C. E. (by letter).—The increasing use of steel tapes or wires for accurate measurements lends a special interest to that part of this paper relating to the method of applying the tension to base-measuring tapes.

The author's adaptation of the principle used on the Missouri River Survey in 1885, by the late O. B. Wheeler, M. Am. Soc. C. E., for this purpose, has many convenient and ingenious features. By improving the method of attaching the tape and weight to the bell-crank, and by providing means for making the small adjustments required to bring the tape in position over the stake, the author has made an improvement over the old wooden triangle with a knife-edge in the corner; but it would seem that he had stopped short of providing a practical instrument for actual work under any but exceptional conditions. The adjustment for the height of the tape above the ground seems to be very limited, the actual limit depending upon the length of the legs of the tension frame, and the softness of the ground. If the earth is so soft as to allow these legs to be pressed into it any great distance it is certainly not ideal for accurate measurements, and it is seldom that one finds the ground so level that he can avoid a variation of 2 or 3 ft. in the height of the end marks of the tape without frequent changes of grade. This, however, is a detail that might be remedied; the real question is: Can this style of tension appliance be made sufficiently portable to justify its replacing the spring balance?

The possibility of the introduction of errors through the use of the spring balance cannot be denied, yet with proper precaution it is capable of giving quite accurate and reliable results. It is a comparatively easy matter to test the constancy of the balance with a

known weight, though, as the author states, to determine the actual tension on the tape an allowance must be made for the difference between the readings of the balance when vertical and when horizontal. Mr. Sabin.

The steel tape is capable of giving results of considerable accuracy, without great refinements in the preparation of the line and the method of use. It finds its greatest usefulness in this field, and it is not wise to multiply contrivances, unless a distinct gain in accuracy is made. With a spring balance and a tension frame of wood, that may be made in a few minutes, the writer has measured short bases with such accuracy that the error of the first quadrilateral off the base was greater than the portion of the error in length of base which could be charged to the manipulation of measurement. While no single step in the method is thought to be new or original, as it is taken in the main from Professor Jäderin, it may be described as a whole to show that sufficient accuracy for most purposes may be attained with very simple appliances.

The tape is supported by wire nails driven horizontally in stakes placed 25 ft. apart along the line. The stakes to hold the end marks are 2 x 4 ins., well driven. The mark at either end of the tape is referred to one edge of the head of a small brad, driven in the top of the 2 x 4-in. stake so that the head is nearly flush with the head of the stake. The alignment and grade are determined in the ordinary way. The tension frame or tape stretcher consists of a wooden handle 5 ft. long hinged to a short piece of 2-in. plank forming a foot-plate. The operator places the foot-plate a short distance beyond the stake, at the forward end of the tape, and stands on it, facing the tape. The hook of the spring balance is attached to the tape, while the ring at the other end of the spring balance is fastened to the handle of the stretcher by a wire loop which may be moved up or down on the handle, thus permitting the elevation of the tape to be adjusted quickly to any ordinary height of stake. The operator has a staff which he thrusts in the ground some distance back of the forward stake, and grasps both staff and handle, thus forming an A. This enables the operator to give a steady pull on the tape. The rear end of the tape is held by a similar stretcher without the spring balance.

Six men are required for accurate work, as follows: Two observers, one recorder, two men to run the stretchers, and one to read the thermometer at the 50-ft. mark and assist in carrying the tape forward. The operator at the rear end is directed by the observer at that end, while the recorder stands directly over the spring balance, and directs the forward operator. When the 100-ft. mark of the tape is even with the edge of the rear brad, say the forward edge, the rear observer calls "read" and if at that instant the spring balance gives the correct indication, the recorder repeats the word and the forward observer reads, on an ordinary celluloid-edged scale, the distance from the zero

Mr. Sabin. end of the tape to the forward edge of the brad in the forward stake. This reading (usually taken in five-hundredths of a foot) is repeated as many times as desired, not less than three, and recorded with the thermometer reading. The tape and stretchers are then carried forward 100 ft. and the operation repeated.

One base of 22 tape lengths was measured three times in June with one tape and three times in November with a different tape. The actual time required for each measurement and the indicated lengths of the base are shown in Table No. 1.

TABLE No. 1.

Measurement number.	Time of measurement, in minutes.	Temperature in degrees, Fahrenheit.	Reduced length.
1	76	69	2181.827
2	60	68	2181.926
3	45	66	2181.892
4	48	46	2181.862
5	36	47	2181.848
6	40	48	2181.847
			Mean 2181.867

$$r = 0.024; \quad r_o = 0.01 = 1 \text{ in } 218\,000.$$

The work should be carried on rapidly, for the accuracy of the measurement depends upon the fidelity with which each stake in succession holds the end mark while the tape is carried forward. There is no place or need for "leisurely" determinations.

If the spring balance is considered too unreliable, then it would seem that a small wheel furnished with ball bearings would be more easily manipulated than the bell-crank. A wire connecting the tape with the weight would pass over a groove in the circumference of the wheel, and the vertical adjustment of the wheel would be provided for by an adjustable A-frame having several pairs of grooves to receive the axle.

When tapes or wires are used in the measurement of primary bases, where extreme accuracy is desired, the use of the spring balance cannot be recommended. In the compound-wire base apparatus of the United States Lake Survey the spring balance was tried and discarded for the ball-bearing wheel. As used thus far, the wires of the apparatus are so long (1 km.) that much time can be spared for preparing stable end marks, and for setting up the apparatus, one tape length being all that is ever measured in one day. The tension wheels of this apparatus seem to leave little to be desired, in point of accuracy, but as the wheel supports are designed for use with either six or twelve wires side by side, they are much too unwieldy for a portable appar-

atus. All the accuracy pertaining to the use of the wheel, however, could be realized for one tape by the simple appliance just mentioned, and the advantage of having the tension automatically maintained without the use of thumb-nuts or levers is at once manifest. Mr. Sabin.

OSCAR ERLANDSEN, M. Am. Soc. C. E.—The subject of this paper is of interest to almost every member of the profession, because, whatever may be his special field of activity, he has at one time or other had experience in precise surveying; moreover, the field covered by the paper is one in which great improvement has been made during the past few years. Perhaps not much more can be expected in the way of increased precision, but there is room for further improvement in the reduction of the time consumed. Mr. Erlandsen.

During the past few years the Department of Bridges of the City of New York, in connection with the surveys for the various bridges over the East River, has developed devices intended to decrease the time required without decreasing the degree of precision. As will be shown, these devices compare very favorably, in precision of results, with those described in the paper. While in simplicity and flexibility or adaptability to conditions, varying all the way from those found in the crowded down-town business districts to those found in the practically unimproved and uninhabited portions of Long Island City, they compare even more favorably.

The tape used is a steel ribbon, $\frac{1}{8}$ in. wide, $\frac{1}{16}$ in. thick and 200 ft. long. It is provided with a spring balance at one end and also with a turnbuckle at each end for the regulation of the tension. The temperature for each measurement is obtained by means of a mercurial thermometer. The thermometer and spring balance were both tested at Washington and found to be correct. The tape is supported at intervals of 25 ft., under a tension of $12\frac{1}{2}$ lbs., but the points of support are not necessarily level. All that is necessary is that they shall all be on the same grade for any one tape length, but it is not necessary that this grade shall be the same for consecutive tape lengths. Moreover, the points of support are only temporary, and are set up anew for each measurement. Stakes, therefore, are dispensed with. To meet the requirements of supports that can be readily set up and adjusted to any grade, the apparatus shown on Plate XVII was devised. The intermediate supports are wooden rods, 1 in. thick by 2 ins. wide, shod with steel points. They are usually and conveniently aligned with a transit. Each rod is held by means of a special extension-leg tripod, the head of which is provided with two pairs of opposing thumb-screws. Along the center line of each rod is a line of holes $\frac{1}{2}$ in. apart. Pegs are placed in these holes in the rods on the grade of the end supports, the position of each being determined by eye, by sighting over the end supports. The holes in the rods being $\frac{1}{2}$ in. apart, each point of support is within $\frac{1}{4}$ in. of the true grade.

Mr. Erlandsen. To each end of the tape is attached a piece of light-weight plumber's brass chain, which passes over the end support to a pin driven into the ground, as shown on Plate XVII. The end supports are adjustable wooden crotches. Along the center line of each of the two pieces forming the crotch is a line of holes which, with a small bolt, provide for the adjustment of the crotch at any desired height. To make a rigid frame of the crotch, the lower ends are hinged to a connecting bar. The end of each measurement is marked on an adjustable table specially designed for the purpose, as shown on Plate XVII. Its top is a steel plate, 6 ins. square, on the upper side of which is pasted a sheet of paper, on which the end of the measurement is marked with a sharp pencil. On the lower side of the plate is a hollow cylindrical lug, which fits over the top of an iron bar. A thumb-screw in the lug permits of clamping the table on the bar at such height that it just touches the tape. Where possible, the bar is driven into the ground. In other cases the bar is set in a heavy cast-iron base and clamped. The elevations of the steel tables are obtained by means of the ordinary engineer's level and rod.

The following examples will illustrate the degree of precision attained. The base of the triangulation for the Blackwell's Island Bridge was measured four times in December, 1900. The results, reduced for grade and temperature, were—

1671.030 ft.
1671.028 "
1671.028 "
1671.060 "

The last was discarded because high winds prevailed while it was being made. The variation of the other three from their mean is less than 1 in 2 000 000.

The distance between two monuments in Long Island City on the center line of the same bridge was measured in January, 1901, and remeasured a year later. The results were 3298.146 ft. and 3298.148 ft., which differ from their mean less than 1 in 3 000 000.

The speed attained in these measurements is almost uniformly 400 ft. per hour.

Mr. Andrews. HORACE ANDREWS, M. Am. Soc. C. E. (by letter).—It is to be hoped that this paper may lead our makers of surveying instruments to adopt some of the suggestions of the author. The first change mentioned is an evident improvement. The arrangement suggested has been long used on vertical circles of the higher grades of theodolites. The addition of a sensitive level to the vernier of the plane-table alidade was suggested by Professor Jordan, and a drawing and description of the device are given by him. Professor Jordan also suggests the independent leveling of the alidade at right angles to the

METHODS OF MEASURING BASE LINE FOR EAST RIVER BRIDGE No. 4.

line of sight, without releveling the plane of the table.* He also Mr. Andrews. refers to the level attached to the vernier as being an advisable adjunct for the tachymeter theodolite.† Again, in referring to the measurement of vertical angles with the theodolite, he calls attention to the need of a level attached to the vernier which can "be brought exactly into play with each individual sight," by means of a suitably attached tangent screw. Professor Jordan also used an arc of large radius, with divisions on celluloid, for reading vertical angles to the nearest minute, the instrument having also a full circle, divided on silver, with two verniers, for more precise determinations.

The second improvement, the increased radius of the arc of the vertical circle, would seem less essential. If a circle of small radius is well divided, and sufficient magnifying power is used, a reading to a half-minute should be easily possible.

However, a larger radius may be used, even as large as that shown in the dotted circle of Fig. 4, Plate XXII,‡ by attaching an arc of suitable length to the eye-piece and object-glass ends of the telescope. This is done with certain English instruments, and the arrangement has the decided advantage of permitting the use of two verniers. Where only one vernier on the horizontal limb exists, eccentricity errors can be rendered of no account by adopting suitable methods of observing, but with only one vernier to the vertical arc there is no method of procedure in measuring vertical angles whereby the errors of eccentricity may be eliminated. The best that can be done is to determine the amount of the error due to eccentricity and allow for its effect upon the vertical angle measurements. This determination is a tedious process; it is sometimes attempted with sextants, but rarely, if ever, with the vertical circles of transits.

A complete circle possesses many advantages. It could be arranged so as to be removed, with its attached level and verniers; it could then be carried in a small case, and would be safe from injury. Such detachable circles are sometimes used with the higher grades of theodolites. With the complete circle, the vernier need not be double, so as to read plus and minus angles. It can be arranged to read "zenith distances;" that is to say, the reading when horizontal would be 90 degrees. Instead of recording the angle, $-1°$, the zenith distance, $91°$, would be used, while $89°$ z. d. would correspond to $+1°$ of vertical angle. A constant source of mistakes would thus be avoided, while the rapidity of reading would be increased.

Professor J. E. Hilgard's reports of tests of theodolites may be read with profit by anyone interested in examining instrumental errors. In the United States Coast Survey report for 1856, p. 315, he refers to the

* Vermessungskunde. 1877 edition, Vol. 1, p. 647.

† Same, p. 606.

‡ *Proceedings*, Am. Soc. C. E., December, 1901, p. 1127.

Mr. Andrews. examination of the parallelism of the vertical axes and suggests a method of examination as follows:

"After leveling the instrument as nearly as may be, revolve the circle about the alhidade, the latter being held in its position by the hand, and watch the indications of the striding level, which will not change if the two axes are parallel."

The references the author makes to "the motion to which a transit is subject, even under ordinary conditions," as revealed by the sensitive vernier level, would probably indicate a lack of parallelism of the vertical axes. Professor Hilgard's test would reveal such a source of error.

The author refers to the slide rule as if it were solely used for ascertaining the correction depending upon the sin.[2] of the angle. The 50-cm. slide rule of Porro, which has been used for many years, was also designed for computing the quantities corresponding to $\frac{1}{2}$ sin. $2a$, necessary for obtaining differences of height. By arranging the slide rule in circular form, similar to the "pocket calculator" of W. F. Stanley, the unit of length could be as large as necessary, while the diameter of the circle would still be small enough to render the instrument quite portable.

Perhaps the newly-described Hammer-Fennel's Tachymeter, which does away with all computation, giving both horizontal distance and difference of height, by means of a diagram reflected into the telescope and seen at the same time with the stadia rod; may prove successful, and supersede both vertical circle and slide rule. The novelty and ingenuity of this device should stimulate our instrument makers, and show them that a field for improvement and invention exists.

The writer has often deplored the absence of a circular level for the preliminary leveling up of the ordinary leveling instrument. Such circular levels are very commonly used on foreign instruments, and facilitate very materially the operation of setting up. Judging from the high praise given to the device known as the "*feste Loth*"—the immovable plumb-bob—by the Germans, it would seem worthy of introduction by some of our dealers. In windy weather much time is lost with the swinging plumb-bob, and the engineer adopts all sorts of expedients to prevent the loss of certainty in his plumbing; his makeshifts, however, do not always prove successful. The writer has never heard of any device proposed by our instrument makers to facilitate the setting up of a transit, and to supersede the usual, hanging, swinging plumb-bob.

The shifting head used on our transits, has been a very commendable improvement, and has attracted favorable attention in other countries. The writer has an excellent level tripod which is provided with substantial steel points with projecting lugs, to allow the points to be

firmly shoved into the ground by the pressure of the foot; and can testify to the value of the device. As made by a well-known firm in this country, the points and lugs are too small and unsubstantial to give good service. Mr. Andrews.

Perhaps too much is sacrificed to convenience and portability with our instruments. The writer has sometimes found it almost impossible to use a wye-level in very windy weather, on account of the deficiency in torsional resistance of the tripod. It is easily possible to make tripods so rigid that the motion from wind will be imperceptible, but such tripods are not quite so comfortable to the shoulders of the one who has to carry the instrument.

Our instrument catalogues are notably defective in their omission of the value of the length of the level divisions, the focal length and aperture of the telescopes, and their magnifying power. The weights of instruments, tripods and boxes are sometimes given in foreign catalogues, and such information is often of interest.

Some instrument makers attach the level divisions to a metal scale which is suspended over the tube. It is claimed that with extremely sensitive levels the etching of the divisions on the tube will cause a gradual change in its radius of curvature. To prevent this, it has been suggested that the divisions should be etched on the inner surface of a glass tube which would surround the level tube and be nearly in contact with it. With either the metal scale or an etched scale on a surrounding tube it would be possible to provide means for effecting a slight longitudinal movement, and thus facilitate what is now a somewhat tedious adjustment.

In speaking of leveling the theodolite, Professor Jordan says:

"This is best made by imagining the level axis changed in place. If, for example, the bubble-center reads 50.4 div., and after reversal reads 47.6 div., then if it is made to read 49.0 div. we can expect it to remain correctly in level at this reading. This new normal point, 49.0, and a few points equi-distant therefrom can be designated on an attached scale."

This "attached scale" already exists, as above remarked, on some of our instruments, it only needs facilities for a slight longitudinal adjustment by a suitable slow-motion screw.

George Aymar Taber, Assoc. M. Am. Soc. C. E.—It may be interesting to know how accurately work can be done in measuring distances with an ordinary 100-ft. steel tape, as this problem is one that often has to be met by almost every engineer. Mr. Taber.

In running the line for the Central Park Tunnel, on Section 7 of the Rapid Transit Railroad of New York City, it was necessary to obtain as accurately as possible the distance across the northwest corner of Central Park from 104th St. and Central Park West to Lenox Ave. and 110th St., a distance of 1 828 ft. This line ran up

Mr. Taber. and down hill, through the trees, bushes and shrubbery of the Park, varying in elevation over a range of about 109 ft.

The measurement was made with an Eddy 100-ft. steel tape, standardized for a pull of 12 lbs. when suspended at full length in the air at a temperature of 62° Fahr. On account of the steepness of the slopes, it was necessary to measure a considerable portion of the line in short lengths, and the question arose as to what pull to give to the tape for distances of less than 100 ft. To decide this, a base line was laid off 50 and 100 ft. long, on a level sidewalk, by means of a 50-ft. Keuffel and Esser, spring-balance, compensating tape. Then the Eddy tape was applied to this base, to determine the ratio of pull to length of tape. This ratio was found to be practically a constant, so that 6 lbs. pull was necessary for a distance of 50 ft., 3 lbs. for 25 ft., etc., the tape being at all times suspended in the air.

The line across Central Park was measured twice in this manner, once in October, 1900, and again, by a different party, about a month later. Each portion of the line as measured was corrected for temperture at the rate of 0.007 ft. per 100 ft. of length for each 10° of temperature above or below 62° Fahr. The variation between the two measurements was found to be only 0.034 ft., or less than 0.002 ft. per 100 ft. of length. The only outfit used in this work, besides the tape, consisted of a common spring balance, a thermometer, two plumb-bobs and a "Locke's hand-level." The latter was used to sight along the tape from one end toward the other, to be sure that both ends were held at the same elevation.

This method of measuring was found to be so accurate and rapid that it was adopted, and has since been used for all work on Sections 7 and 8.

Vol. XXVIII. MARCH, 1902. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE BOHIO DAM,

Discussion.*

By Messrs. ALLEN HAZEN, WILLIAM H. BURR, EDWARD P. NORTH, THEODORE PASCHKE, A. G. MENOCAL, H. N. PHARR, EDWIN DURYEA, Jr., and C. A. SUNDSTROM.

ALLEN HAZEN, M. Am. Soc. C. E.—The author has made use of a formula, for computing the flow of water in sands, which was originated at the Lawrence Experiment Station of the Massachusetts State Board of Health. This formula was established by certain experiments made to secure the necessary information for use in constructing filters, and particularly for use in constructing the Lawrence filter, which was just being undertaken. Mr. Hazen.

The principal object of the Lawrence Experiment Station was to secure scientific information regarding the process of filtration. The applicability of this information depended upon the discovery of a sure method of comparison by means of which the materials used in the experimental filters could be compared with the materials which it was proposed to use in other filters, and which were so numerous that detailed investigations of them were impossible.

The formula as devised and quoted may be divided into several parts, some of which were new, and some of which had long been known. The discovery that the velocity of water in any given

* The discussion (of the paper by George S. Morison, M. Am. Soc. C. E., printed in *Proceedings* for January, 1902), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to April 25th, 1902, will be printed subsequently.

Mr. Hazen. sand varies directly as the head, and inversely as the distance, is attributed to Darcy. It was carefully checked at Lawrence and found to be correct. This knowledge was useful, but it was imperatively necessary, in addition, to know the coefficient for various materials. It was not enough to know that v would vary with $\frac{h}{l}$. It was necessary to know what v would be for any given material and slope.

The novelty of the Lawrence work in this direction consisted, first, in improvements in the methods of mechanical analysis of sands; second, in establishing a definition of the effective size of sand; and third, in finding the relation between this effective size and the velocity.

The problem was a somewhat complicated one. The ground was entirely new, and the information was required for immediate use. As the experiments were instituted and carried out, various forms of apparatus were used successively; but the final and most successful results were obtained from galvanized-iron cylinders containing the material under examination, supported by graded gravel layers at the bottom, through which a flow of water was maintained at accurately controlled and determined rates. The losses of head in determined distances, ranging from 12 to 48 ins., were determined by attaching glass tubes to pet-cocks in the sides, and observing the differences between the water levels in the various tubes. These observations were always confined to portions of the sand layer well below the surface, to avoid the additional head required to force the water into the sand at the surface, for this additional head was often greater than the friction in a considerable depth of sand. The appliances were such that the apparatus could usually be kept in continuous use for weeks or months; and the most reliable results, particularly for fine sands, were obtained after considerable lengths of time.

The effective size, as defined at Lawrence, was that in which 10% of the material was finer and 90% of it coarser than itself, the size of each grain being taken as the diameter of a sphere of equal volume. Methods of analysis were developed to allow this determination to be made with considerable accuracy. The procedure of taking the effective size as stated was purely empirical. It was selected because it brought the materials used in the Lawrence experiments having different uniformity coefficients (that is to say, materials in which the amount of mixing of coarse and fine grains were very different) into their proper relations with each other.

In the nine years since this formula was originated, some additional data have been secured. Experiments by F. P. Stearns, M. Am. Soc. C. E., have furnished some of the best of these results. Altogether, these

data have been less numerous than could have been desired, but they have been reasonably consistent, and have shown the correctness of the formula. Of course, the value of c varies somewhat with the conditions. On an average, it is somewhat less than was at first supposed. Mr. Hazen.

The flow of water through sands has been investigated upon independent lines by Professor F. H. King,* of the University of Wisconsin, who has developed formulas which give, apparently, for a given sand, a somewhat lower discharge than is computed by the Lawrence method. Direct comparison, however, is difficult, because the effective size, as defined by Professor King, is an entirely different quantity from the effective size as defined in the Lawrence method.

Professor Philip Forchheimer, of Graz, Austria, has made an interesting compilation of the experiments on the flow of water through sands,† beginning with Darcy's work in 1856, and coming down to the present time. He has computed and prepared a table of the values of c, in the Lawrence formula, as deduced from the experiments of four European observers, all ante-dating the Lawrence work. The values which he thus finds range from 310 to 1 110, averaging 442. This comparison is somewhat uncertain, because of differences in the methods of computing the grain size used in the various cases. Probably the effective sizes by the Lawrence method are always less than the grain sizes taken by the other investigators; and if this is so, the factors found by Forchheimer from their results should be increased by the square of the ratio between the grain sizes as computed by Forchheimer and the effective sizes as defined by the Lawrence method. This might double the value of c, although Forchheimer writes that, in his judgment, the ratios of grain size to the effective sizes, on an average, would not be more than from 1.24 to 1.30, corresponding to an addition of from 54 to 69% to the values of c as computed by him. Taking this into account, the general agreement of the experiments among themselves and with the Lawrence experiments is quite satisfactory; and, as Forchheimer states, the value of the comparison is greater because each of the observers was ignorant of the others, and none of these results was known to us at the time the Lawrence experiments were made.

As to the application of the formula to the computation of the probable flow of water through bodies of sand enormously greater than those used in the experiments, the speaker is unable to see any rational ground for objection to such use. In experimenting with pipes, the loss of head in 100 or 1 000 ft. of pipe, may be determined, and, assuming that the connections are made on the sides of the pipe sufficiently far away from the points of entrance and exit, no one would doubt that the rates thus found would be applicable to lengths

* U. S. Geological Survey, 19th Annual Report, 1899.

† In a recent number of the *Zeitschrift des Vereines Deutscher Ingenieure*, Vol. XXXXV.

Mr. Hazen. of pipe indefinitely longer than those used in the experiment. The speaker believes that the same is true of sand, but with this difference, that the motion of water in sand is many times slower, the interstices are enormously smaller, and all the actions are of such a nature as to establish themselves normally in a very short distance. The few feet of sand on which experiments have been made may therefore be quite as adequate, as far as length is concerned, as the lengths of pipe which have been used in most of the experiments to determine the flow of water in them.

The conditions of the sand in and under a large dam would probably differ somewhat from the conditions of the sand in the filtration experiments. The experiments made by Mr. Stearns, at Clinton, were more nearly comparable to the conditions in a dam, for the materials were usually placed in layers and rammed. Under these conditions, the values of c in the formula averaged about 600. Generally speaking, the sand in a filter is in the most favorable condition for the passage of water, and the value of c is at a maximum. The conditions in and under a dam, so far as they are different, all tend to lower the value of c, and, consequently, to reduce the amount of seepage.

Mr. Burr. William H. Burr, M. Am. Soc. C. E. (by letter).—Taking the North Dike of the Wachusett Reservoir of the Metropolitan Water Supply for the City of Boston as his pattern, in some of its principal features, Mr. Morison develops a rather striking plan, involving some highly interesting but novel and untried features, for the dam near Bohio on the Panama Canal Route. The physical features at the site of the proposed Bohio Dam are only partially set forth by the author, but it is essential, for the complete appreciation of the conditions under which this structure must be built, to exhibit all the results of the borings made by the Isthmian Canal Commission at the various tentative sites, of which there are six, Fig. 2 showing but five. The omission of Section *E*, a short distance up stream from *F*, is not of crucial importance, but that section is needed to complete the information obtained by the Commission, and aids one in understanding how greatly variable are the subsurface strata at and near the vicinity of the dam site.

In reality, that excessive and erratic variation in the strata of material disclosed by the borings is one of the most striking features of the whole situation. It exhibits clearly, among other things, the danger of drawing any conclusions as to the impermeability of the upper strata of material, which, as Mr. Morison indicates, are either clay, or sand, or a mixture of the two. Further, it is essential, in dealing with this general question, to realize fully that the order of the strata as found at one section may be radically different in one or more of the other sections; indeed, that is generally the case. Further than that, at the same elevation and in the same section, prac-

tically clear coarse sand may be disclosed by one boring and blue clay with little sand by another boring perhaps not more than 300 ft. away. Again, yellow clay and sand may be found at the surface of one of the same borings and at 128 ft. below the surface in the other. Indeed, the one persistent feature of the disclosures by the borings is the utter lack of uniformity of conditions on which any conclusions common to different sections can be based. The masses of material seem to be in the most irregular and irregularly limited strata or pockets. The sand is of all degrees of fineness or coarseness, from the finest to coarse gravel, and apparently from clear sand or gravel to all degrees of admixture of clay, both blue and yellow. Mr. Burr.

There are a few bore-holes in which the standing of the water appeared to indicate impermeable material. In fact, the pure clay and some admixtures of sand and clay may safely be considered impervious, but the limits of impermeable areas have not been defined, and cannot be predicted from the information gained by the Commission in its borings. The excessive variability of that feature is a part of the general variability to which reference has already been made as one of the prevailing physical features of the situation. The sections or tentative sites along which borings were sunk by the Commission are lettered *A*, *B*, *C*, *D*, *E*, and *F*, *A* being the farthest up-stream section and *F* the farthest down-stream section. A stretch of about 1 300 ft. along the course of the river between Sections *D* and *E* contains but two or three bore-holes, and, consequently, the information as to it is meager, the reason for so few borings in that vicinity being the unpromising character of the locality for the purposes of the Commission. In Section *A*, the borings, about 350 ft. apart, are generally in clay, there being little clear sand disclosed. In that section, apparently, the river water is not in direct contact with the pervious substrata. The borings made at Section *B*, however, show the water of the river coming in contact with the heavy layers of sand disclosed by them, thus making a free flow from the river to the pervious substrata. In Section *C* the river bed is also of sand, and there is every reason to believe, from the results of the borings there, that the water may find its way through the mixture of clay and sand down to the heavy masses of clear sand reaching nearly down to the bottom of the geological valley. The same general observation may also reasonably be made in connection with Section *D*, the bed of the river being in a layer of clay and sand with clear sand underneath it. The borings made at both Sections *E* and *F* show that the river is in direct contact with the heavy mass of permeable sand extending practically to the lowest portion of the materials penetrated, or to rock.

In these observations, material which has been called sand is in some cases coarse enough to be classed as gravel. It will thus be seen that the total statement of the information actually disclosed by the

Mr. Burr. borings at the various sites demonstrates conclusively a probability so strong as to amount to practical certainty that, not only is the water of the river now in free connection with the pervious substrata of sand and gravel, but that the water of the lake, with its 90 ft. additional head, would be in much freer connection.

Again, if it could be assumed that a blanket of impervious clay or mixture of clay and sand is uppermost over pervious material, it is in the highest degree probable that the weight of 90 ft. of water above it would in many places produce settlement cracks through which water would readily find its way to the pervious strata below. These physical features of the situation induced the Commission to believe that in the present state of information its estimates and plans should be based upon a structure which would close completely the geological valley, and thus shut off absolutely any possibility of dangerous or prejudicial seepage. In this connection it is to be remembered that it is not danger to the structure alone which is to be guarded against, but any degree of seepage which might prejudice the supply of water in the summit level of the canal formed by the lake.

The location at Section *F*, for the purposes of plans and estimates, was adopted by the Commission, as stated by Mr. Morison, for the reason that the maximum depth from sea level to rock was 128 ft., which is but 13 ft. more than the depth reached under one of the piers of the New East River Bridge. It is possible that the deepest caissons at Bohio might be carried to rock by the pneumatic process under the full head of 128 ft. This selection would perhaps appear more suitable if Mr. Morison had stated that the deepest rock at the site selected by the French engineers is 143 ft. below sea level. It is not impossible that that site might not eventually be adopted, but it was deemed best not to select a site for the purpose of plans and estimates against which the objection of depths far beyond those already reached under compressed air might be brought. Indeed, the writer is not sure that Section *B* might not prove to possess controlling advantages, as it is short, and the maximum depth of rock is less than 140 ft. It is possible, also, that the open-dredging method might be available for putting in place the deepest caissons, but it involves considerable uncertainty as to the closing of the lowest part of the geological valley, where the material might be most pervious, and, as already stated, the Commission desired to eliminate as far as possible all uncertainties, even at some additional cost.

Again, another material advantage offered by Section *F* arises from the fact that within the banks of the actual river the deepest rock is less than 100 ft. As shown by the elevation in Fig. 4, the remainder of the structure in the deepest part of the excavation could be built by sinking caissons on dry land, and mostly at a considerable distance from the water of the river. That portion of the dam, about 1 300

ft. in length, is situated along the high clay plateau on the left or westerly bank of the river. It is to be anticipated that water stands in the substrata at practically the elevation of the water in the river, or at least at sea level, but if pits are excavated in that plateau down into the pervious strata, ample experience shows that the water in them could readily be pumped down to a considerable amount, which the writer believes would prove to be not less than 30 or 40 ft., with reasonable pump capacity. Such depressions of subsurface water elevation, by the operation of pumping, have frequently been effected in engineering works; indeed, the ease by which this can be done has proved to be an objectionable feature of many water supplies drawn from subsurface water-bearing strata. It may confidently be anticipated, therefore, that by these simple and available means of pumping down the head of water around the caissons sunk throughout the deepest portion of Section *F*, the head of water producing pressure in the air-chambers of the pneumatic caissons may be reduced below 100 ft.; indeed, the writer believes it would prove to be materially less than that. Mr. Burr.

It is thus seen that the construction of the dam on the site adopted by the Commission, for the purposes of its plans and estimates, involves no new or untried processes or features more novel than those due to naturally varying local conditions. In other words, this construction is quite within the limits of engineering work already accomplished, so that the estimates of the Commission for this dam cannot be attacked successfully. It is not certain that it would be necessary to carry pneumatic caissons the entire distance to bed-rock in this location. If a depth were reached within a short distance, perhaps 10 or 20 ft., of that rock, or if small, deep places should be encountered, there are various methods, including that of sheeting or other devices, by which the seepage of water could be positively and completely shut off below the cutting edge.

On page 258 of the Commission's Report occurs the following portion of a paragraph:

"A less expensive dam at Bohio has been proposed, but through a portion of its length it would be underlaid by a deposit of sand and gravel pervious to water. The seepage might not prove dangerous, but the security of the canal is directly dependent upon this dam, and the policy of the Commission has been to select the more perfect structure, even at a somewhat greater cost."

It is barely possible that a more detailed examination of the vicinity of the dam would demonstrate the feasibility of the type set forth by Mr. Morison, although the writer doubts it, but if a structure of that character had been adopted by the Commission its plans would have been open to serious criticism as involving elements of uncertainty to a degree that cannot be measured or predicted.

Mr. Burr. The writer has not been able to confirm the low estimate which Mr. Morison places upon his proposed earth dam, and is inclined to think its cost would be nearer $4 000 000 than $2 500 000. Whether that be so or not, however, the additional estimated cost involved in the Commission's plans is abundantly justified by the absolute certainty in the character of the results obtained by it in connection with a feature positively essential not only for the safety of operation of the canal but for its actual existence.

The computations of seepage made by Mr. Morison can scarcely be relied upon as even approximate, for the reason that the data on which the formula used are based were derived from experiments on masses of sand almost infinitesimal compared with those under consideration, and also upon conditions which it is practically certain are radically different from those existing at Bohio. That formula applies only to sands having effective diameters ranging from 0.1 to 3 mm., and with a uniformity coefficient lower than 5. It also presupposes that the texture, so to speak, of the sand is uniform. It is not at all unlikely, in such material as that which exists at Bohio, that there may be places so free and open as practically to form small channels. In fact, there is no basis for any prediction as to the existence of conditions which would make it even approximately accurate in this connection to use a formula derived from experiments in small filters, even though that formula be admirably adapted to all other filter conditions.

The type of dam which Mr. Morison has developed and set forth certainly is most interesting, but, under conditions existing at Bohio, it involves novel and untried features, the efficacy of which can be established only by further engineering experiences, as well as assumptions which yet remain to be justified.

Mr. North. EDWARD P. NORTH, M. Am. Soc. C. E.—It is, doubtless, a matter of pride to all that, after twenty years of varying plans proposed by the European engineers for the Panama Canal project, the last resource is in close conformity to the plan proposed before this Society in 1879 by Charles D. Ward, M. Am. Soc. C. E., to build a dam at Bohio and carry the summit level at approximately the same height as proposed by the Isthmian Canal Commission. But it is doubtful if Mr. Ward would propose a dam which necessitated work in caissons under an air pressure balancing a water column of more than 130 ft.

There seems to be an ambiguity as to the exact depth, as in one part of the Commission's report a minimum depth of 128 ft. below tide is mentioned, and another part of the same report reads that the cofferdam is to be 8 ft. above tide. As the dam site is some 13 miles inland, it is assumed, subject to correction, that the air pressure in the caissons will be that due to 136 ft. of water, or, virtually, 5 atmospheres.

It is assumed, and all will readily agree, that healthy men sustain small inconvenience when working 4-hour shifts under pressures of

about 50 ft., but at 75 ft. deaths are to be expected, and at 100 to 110 ft. they occur with unpleasant frequency even among picked men; also, that in the Great Lakes 110 ft. is about the limit of divers' work. All these experiences have been had when the temperature of the water has been between 40 and 50° Fahr. Whereas, at the Bohio Dam site the temperature of the water is about 90°, as the mean annual temperature—which governs, approximately, the temperature of deep-seated springs—is about 90°, and further, this is the temperature assumed by Mr. Allen Hazen in his percolation formula for that locality. This high temperature in the caissons must add materially to the distress of those working in them. When, to these difficulties is added the fact that, as far back as the seventeenth century, maps have designated the Caribbean front of the Panama Route as "The Place of Bones," an evil reputation that has ever since been maintained, the necessity, as implied in this paper, for designing the least expensive safe structure adapted to the particular case in hand, is apparent. Unless the head of water in the Chagres River can be pumped down to reduce the pressure in the caissons so that life will not be in great jeopardy, a procedure that is probably practicable during low-water flow of the river, the saying of 40 years ago, "that each tie on the Panama Railroad cost a human life," will be repeated, as to the depths in feet to which the caissons are sunk. Mr. North.

Unfortunately for the advancement of engineering knowledge, a courteous regard for the expressed wishes of the author prevents any consideration here of the reasons for selecting a route requiring air-locked foundations more than 130 ft. deep, when about 80 ft. would suffice at Conchuda; or why a rock and earth dam at Bohio should be more safe and available than at or below Ochoa and for the San Francisco basin; having in view the much larger flow of the San Juan, which reduces danger from seepage to a minimum.

As there seems to be no tenable doubt as to the stability of the proposed dam, there remains only for consideration the plan and its ability to retain sufficient water for navigation during the annual dry season, or through two or more recurrent dry years. On account of the limited water-shed, 875 sq. miles, difficulty may be apprehended in case there should be two successive dry years, even with the traffic estimated for, and if the canal is made large enough to conveniently pass the traffic between the east and west coasts of this country, which experience with the canals at the "Soo" shows may be expected, it is of vital importance that the seepage or any other waste should be reduced to the minimum.

The speaker suggests that the dam, as shown in Fig. 6,* if turned around, would more effectively retain water and would cost less.

The value of an enrockment at the base of an earth slope, as shown

* *Proceedings*, Am. Soc. C. E. for January, 1902.

Mr. North. by Mr. Stearns, and as used in wet railroad cuts, lies in its preventing the degradation of the toe, which commences by small slides. Dams Nos. 3 and 4, Fig. 6, are requisite to save an indefinite extension of the earth slope, the great length of which is obviously not required for stability. Nor are Dams Nos. 1 and 2 of much economic use in preventing erosion by the feeble waves possible in Lake Bohio, if an embankment of like mass is to be used.

If Rock Dams Nos. 1 and 2 were retained at or near their present proposed locations and the 2 000 ft. of earth embankment were extended out into the lake it would effectually seal a large area on the bottom against the access of water to such portions of the pervious strata mentioned as do not underlie any extension of the heavy and tight blanket of finer alluvial deposit found at the dam site. Both the rock and earth portions of the dam would be preferably deposited in running water, obviating the cost of a temporary dam, ensuring the thorough filling of the rock dam and the puddling of the earth.

Any floods that might occur during the construction of the dam would save a great part of the excavation necessary for the proposed puddle dam. The depth to which the water passing over the dam would cut out the material below it, depends, of course, on the volume and velocity of the water striking the alluvial deposit, modified by the angle of its incidence. While there is small question that with a vertical fall the material would be cut out to the rock by an ordinary flood, the result would be different and less with the water running over the flat slope assumed by a loose-rock dam, particularly if material from the lock excavation was used instead of rock blasted for the purpose.

To whatever depth the cutting extended, the toe of the rock dam would be strengthened by its greater depth, and, on the completion of the dam, an easy and comparatively inexpensive problem in clam-shell dredging would be presented, by which an open ditch could be excavated to the rock and filled with clay to shut off all percolation after the stability of the slopes of the Cubebra Cut was established, and if it was ascertained that water percolated under the embankment.

Mr. Paschke. Theodore Paschke, M. Am. Soc. C. E.—This paper is very interesting, and the plan proposed by the author for the construction of the Bohio Dam, while not entirely original with him, is in the line of the highest degree of rational engineering. The author intimates that the question of seepage may be the only vulnerable point in his plan, and invites discussion on this particular point.

The Isthmian Commission's plan seems to indicate the same trend of thought, inasmuch as that plan involves carrying a core-wall to rock foundation at an unprecedented depth below water.

The writer has had some experience in the tropics, especially in Central America, in the construction of water-works and river im-

provements, and, based upon this experience, he feels called upon to allay any apprehension or fear there might be on the question of seepage as regards this proposed construction of the Bohio Dam; and, however creditable the preceding discussions on seepage are to the gentlemen who so elaborately dwelt upon the subject, it strikes him that those learned discussions on seepage are really unnecessary, and not applicable to this dam at all, for the simple reason that, in the writer's opinion, all that part of Bohio Lake in front of the dam will be silted up and made water-tight, for all practical purposes, in the course of a few seasons' work by Nature herself. Mr. Paschke.

The strata overlying the hills and mountains through Central America have as their base, almost exclusively, volcanic ashes of various compositions, according to the period in which they were emitted. Some have been hardened to a soft rock like sandstone, others have the appearance of fine loam, and others are not unlike burnt clay. All are easily eroded by water, and are carried down by every flood in all the mountain streams in large quantities. They are ground up and mixed thoroughly with vegetable matter, forming a black clay-like silt; a very good water-proofing indeed. The Gigante Spillway will divert the line of flow of the Chagres waters from the site of the dam, and will have the effect of forming a large eddy in the flow in front of the dam, which will hasten the process of silting up.

Indeed, the writer is of the opinion that it is only a question of time when the whole artificial lake, which the proposed dam will form, will be filled with this silt, except the channel necessary for the Chagres waters to flow either to the spillway, during floods, or to the locks of the canal, and that, if no provision is made for such exigency, the ulterior object of creating this artificial lake will be defeated.

While the writer most readily and heartily affirms all the advantages claimed by the author for his proposed plan of the Bohio Dam, he cannot help but deplore the fact that it is designed in the interest of only a lock canal across the Isthmus at that point.

Engineering ingenuity, of an order which can devise a plan to dam the Chagres at Bohio, at once so simple and grand, and so enduring, should find no difficulty in devising means to dam the same river a little higher up in its course and to completely control the flow of its waters at will, removing the only great obstacle in the way of a sea-level canal at this point.

A. G. Menocal, M. Am. Soc. C. E. (by letter).—Mr. Morison deserves the thanks of the engineering profession, and also of all those interested in reaching a satisfactory solution of the Isthmian Canal question, for his timely and valuable paper on the proposed dam at Bohio, on the route of the Panama Canal. The dam, together with the lake created by it, and the Alhajuela Reservoir, as sources of water supply, are of vital importance to the success of the plans Mr. Menocal

Mr. Menocal. recommended by the Isthmian Canal Commission, and the three are so intimately connected with each other that the failure of either of them to accomplish the essential requirements would throw serious doubts into the practicability of the project. They should, therefore, receive the most attentive consideration, and all doubtful elements should be removed, before a route for building the canal is finally selected.

The difficulties involved in the execution of the Commission's plans, as shown by physical conditions developed by a partial examination of the site, are pointed out clearly in the paper; but those difficulties are likely to be enhanced greatly by a more detailed survey, or during the process of construction. Holes deeper than 128 ft. below sea level may be found, or faults or joints discovered in the rock, where the caissons may have to be carried down to greater depth than 136 ft. below low water, before a tight joint can be secured. The writer is not aware that the pneumatic process has ever been carried to such a depth, and, considering the attending labor and climatic conditions, is of the opinion that it cannot be done successfully at Panama. The scheme seems to be in the nature of a hazardous experiment, containing in itself several elements of failure.

The alternate plan, combining rock-fill dams and earth filling, proposed by Mr. Morison, has the advantage of simplicity in the design and economy of time and money in execution, but, in the opinion of the writer, would not meet the requirements of the problem. Such a dam may safely stand the normal pressure of 90 ft., and, with a permanent superabundant supply of water, would probably maintain the proposed level in the lake, but it would not prevent a much greater leakage than can be spared from the water supply available at Panama, even when this supply is enlarged by the proposed reservoir in the upper valley of the Chagres River. The borings made in the vicinity of the dam site, according to the Commission's report, show:

"A variety of material; hard clay, soft clay, sand, and some mixtures of sand, clay and gravel in varying proportions. These materials are found in beds of varying shapes and thickness, not distributed with uniformity and not arranged according to any general law from which can be deduced the characters of the soil at points other than those actually examined. In every section constructed from the borings, strata of greater or less dimensions are found, which are permeable by water."

It is quite evident that ground composed of material as above described cannot be regarded as impervious under high pressure, and the difficulties of driving through it two long rows of sheet-piles to the depth of 60 ft. so as to secure uniformly tight joints, must be admitted. Many of the piles are likely to break or split, while others will be deflected laterally, making large, open joints underground, without marked indications at the tops. Considerable leakage must be expected, therefore, not only through the pervious material repre-

sented in the sections accompanying the paper, but also through the whole submerged area, through the joints, and underneath the sheet-piling. Much of this leakage will come to the original surface and flow freely along the imperfect joints made by the ground and the material loosely deposited between the rock-fill dams. Mr. Menocal.

There seem to be no formulas by which this leakage can be computed. That deduced by experiments by Mr. Allen Hazen, on filter beds with small heads and selected material, is not applicable to the conditions of this problem, as a small change in temperature or in the diameter of the sand grains would give widely divergent results, tending to check faith in the conclusions.

The amount of leakage permissible through the dam is directly proportional to the available water supply, and it seems proper, in this connection, to look into the capacity and permanency of the storage reservoir provided in the plan for operating the canal during the dry season. The Chagres River is the only source of supply, and Lake Bohio, with an area of 38 sq. miles, the main storage reservoir. Another reservoir is proposed to be created in the upper valley of the river by building a dam at Alhajuela, about 10 miles above Obispo.

The Chagres has a well-established reputation as a violent torrential stream. Its flow has been known to vary from a minimum of 350 to a maximum of 136 000 cu. ft. per second. It has been known to rise 35 ft. at Obispo, where the canal falls into the bed of the river, and to rise 39.3 ft. at Bohio. The excessive rainfall and the precipitous slopes of the water-shed, rising in places to thousands of feet, give to the river its torrential character. The records of the last twenty years show that these extreme high floods take place every two or three years, but similar floods of somewhat less violence are not uncommon, and are likely to occur several times during the same rainy season. It is stated in the Commission's report that, above Obispo the Chagres "is in general a clear stream flowing over a bed of gravel; but sand, clay and silt in moderate quantities appear in the lower portion of its course." This statement must have reference to conditions during the dry season, as it is above Obispo where the mountainous water-shed and an annual rainfall of about 130 ins. give the river its torrential features, and where the largest erosion takes place, as shown by the gravel beds referred to, and cliffs from 50 to 200 ft. high on either side of the river, alternately as the current has washed first one and then the other in its tortuous course. Any one who has seen the river in floods knows that its waters are surcharged with sediment. Lieut. J. T. Sullivan, U. S. Navy, in his report to the Navy Department, in 1883, says:

"The flood waters of the Chagres are not only heavily charged with detritus, but with an immense debris as well. Houses, trees, masses of vegetation, rocks and stones are borne in its floods, and in a freshet which occurred in the winter of 1879–80, an iron tank 17 ft. above the level of the railroad track was carried away."

Mr. Menocal. Referring to the rapid silting up of the sea-level section of the canal excavated by the French Company, Alfred Noble, M. Am. Soc. C. E., member of the Isthmian Canal Commission, stated before the Committee on Interoceanic Canal of the Senate that "the only practical solution would be to keep the river waters out (of the canal). Dredging would certainly be too expensive."

In the presence of these well-known conditions, it seems that the necessary result of receiving the river in the proposed Bohio Lake will be the rapid silting up of the lake and the consequent decrease of the water supply; that an attempt to create a reservoir in the upper valley of the river will, also, for the same reasons, fail to accomplish its purpose, and that the water supply cannot be relied upon as sufficient for the purposes intended, or permanent.

Mr. Pharr. H. N. PHARR, Assoc. M. Am. Soc. C. E. (by letter).—"The third plan," proposed by the author, has been of special interest to the writer. In the construction and maintenance of levees on the Mississippi River, along the front of the Lower St. Francis Levee District, in Arkansas and Missouri, about 200 miles in length, embankments solely of earth have been built to withstand greatly varying heads of water, under various and particular conditions and considerations, which have necessitated different heights, dimensions and methods of construction.

The writer's observation and study of the action of earth dams under various conditions and circumstances and of greatly differing character have extended through many years; and the character of the work at Bohio, and the conditions which will govern the building of an earth dam of such dimensions as described by the author are thought to be appreciated.

Although nothing within the writer's work or observation is reasonably comparable with the work and conditions described in the paper, there are some features in particular cases which may be considered.

The levees as generally constructed have an 8 to 10-ft. crown, with slopes of 1 on 3, to 1 on 4, sometimes with broken slopes, or with banquettes of varying height and dimensions. A levee of 20 to 25 ft. in height, to withstand a flood or water height of 2 ft. below the crown, is very usual. However, a particular location or levee (Chute of 38) is presented in Fig. 9, which may not be considered usual, though practically the same conditions and features have been met with several times along the levee line. A general map of the Mississippi River in the vicinity of the Chute of Island Number 38 is shown in Fig. 9. The main or navigable channel of the river has in the not very distant past occupied several beds in this vicinity, as shown by the islands and "old rivers" now deserted by the river and becoming silted up and grown up in cotton wood, willows, etc. The bend

west of Centennial Island, known as Devil's Elbow, was cut off and abandoned in May, 1876. Mr. Pharr.

The map does not show the exact shore and channel lines as at present existing, owing to caving which has recently taken place along the east side of Centennial Island and the west side of Fogleman Chute. The caving at the latter is one of the considerations which determined the location of the levee across Poker Point and back from the river bank as shown. The levee above and around Old River was located safely close to the bank which was sloping and free from caving at that point, the old river being now in process of filling up.

Island Number 38 is shown on the map as now a part of the mainland, though long ago the main channel of the Mississippi was on the west side of it. The Chute thus abandoned on the west side of Island Number 38 is known as the Chute of Island Number 38, and, locally, as Little Old River, but it has been silted or filled up practically by the sediment and overflow of the river. It is scarcely observable at its upper end. The lower end has been very greatly contracted, but was kept open to a certain extent by Frenchman's Bayou, which affords the only natural drainage for a considerable territory. It was the leveeing of this chute, to prevent the ingress of the floods of the Mississippi River and the diversion of the drainage formerly afforded by Frenchman's Bayou, which had to be secured.

The character of the material, of course, is all permeable, being alluvial deposit, a sandy loam; and the foundation or base of the levee immediately across the chute was of a soft muck. An iron rod or pole could be pushed down, merely by hand, into the bottom or sides of the chute for the length of the rod. Water, to the depth of a few feet, was always running through the chute into the river when low or during dry seasons, but when the river was rising the current ran back through the chute, to again reverse and flow into the river as it fell. Low water in the chute was about 8 or 10 ft. above low water in the Mississippi River and in Old River.

On Fig. 9 there is also a profile, on the center line of the levee across the chute, with an exaggerated vertical scale, showing also the grade line, which was raised 2 ft. across the chute to allow for any additional settling which might occur, after the levee was once brought up to grade, beyond that taking place during construction and beyond the usual allowance of 10% for shrinkage, and also to prevent overtopping at this immediate point. Overtopping was likely to occur to the general levee in this vicinity, as the available funds for construction limited the height which could be adopted for the stretch of levee, some 17 miles in length, built at that time.

A cross-section and a plan of the levee, as constructed across the chute, the latter being drawn to the same scale as the profile, are shown in Fig. 9.

Mr. Pharr. On this figure there is also a cross-section of the levee, drawn to true scale, with details of height, distances, slopes, etc. The net height is 35 ft.; crown, 8 ft.; side slopes, 1 on 4, on both river and land side; with an off-set or banquette on the land side, 20 ft. in width and with a slope of 1 on 20. The elevation of the banquette is about the same as the bank on each side of the chute, or the natural surface of the adjacent ground, which is practically a level plane. No core or puddle wall or sheet-piling was used or constructed, the principal object being to obtain an embankment of as great homogeneity as possible, because the foundation and ground were permeable. Three excavations or muck ditches, however, were dug across the chute, one just on the river side of the center line of the levee and one each near the middle of the front and rear slopes, as far as the material excavated would allow. These ditches were merely for purposes of exploration. The whole ground having been built up by the sediment and sand of the river, it was to be expected that many logs and other perishable matter would be found throughout, but only such as could be discovered near the surface by such means was undertaken to be removed. The ditches were about 8 ft. wide and 6 to 8 ft. deep where the material would allow. Other excavations were made in the base in removing perishable material.

The levee was constructed according to the general levee specifications, as far as applicable. The method of carrying up the embankment continously in layers of a certain thickness and well traveled was complied with, to a great extent. Wheel scrapers with about 35 teams were used. At the time, the chute was discharging a stream about 4 ft. in depth into the river with considerable velocity. No effort was made to dam the stream in any way above the levee site, as such would have required about as much time and expense as the proposed levee. The work was begun by depositing earth as far down the bank and as close to the stream along each side as the natural slope of the loose and new earth would permit without being carried away by the current. This was continued until a considerable quantity of earth was deposited toward the toe of the land slope of the levee, the surface or slope of the layers of new earth declining toward the river side. An almost imperceptible sliding or slipping of the whole mass and of the material of the foundation toward the center from each side was seen to be going on. This gradually narrowed the width of the stream, raised the surface of the back-water and increased the velocity of the flow until the new earth began to undermine and the sliding toward the center increased. Finally, the sides came together and effectually dammed the stream, which soon rose to a depth of 10 or 15 ft., but the embankment was easily kept above it as the teams could then cross. The embankment was completed in December, 1898, without interference, according to the dimensions shown by the cross-section in Fig. 9.

Mr. Pharr.

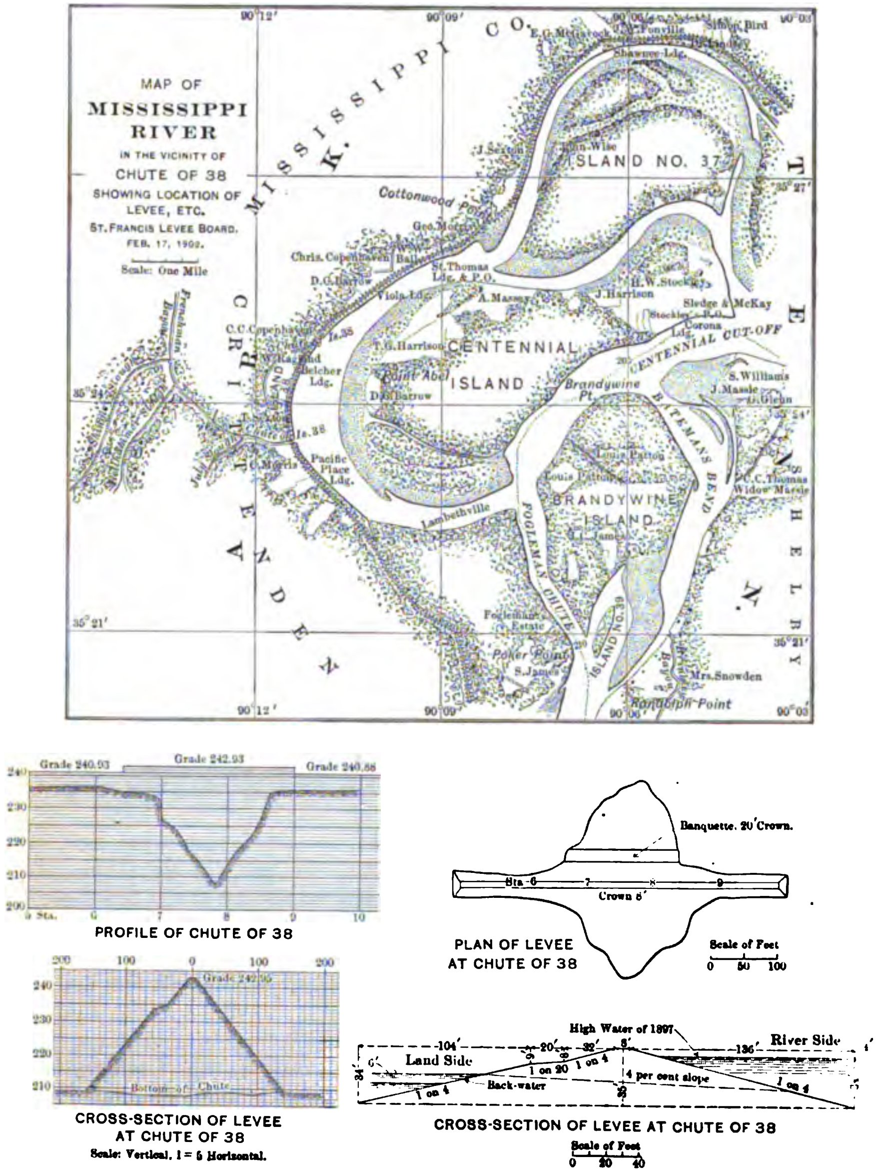


FIG. 9.

Mr. Pharr. The following shows the total number of cubic yards placed in the levee across the chute proper;

Embankment and excavation	21 786.2	cu. yds.
Additional excavation	1 600.0	"
Settling of foundation	3 500.5	"
Total	26 886.7	cu. yds.

This, under a contract for the construction of 17 miles of levee, cost 12.45 cents per cubic yard, or $3 347.39.

The specifications allowed a free haul of 300 ft., but, as borrow pits were obtained upon the four sides of the levee and chute, no over-haul was necessary. Probably a fair estimate of the cost of the levee across the chute only, under separate contract, would be 30 cents per cubic yard, or $8 066.

The surface of the water in the bayou or chute on the land side of the levee continued to rise until, in June and July, 1899, which was a very rainy season, a considerable territory was submerged by the back-water, which caused damage and inconvenience. The first natural relief was drainage through several bayous running in a southerly direction from Frenchman's Bayou and discharging into the Wampanocca Lake, which drains naturally toward the rear, finally reaching the St. Francis River. However, there was no relief in this direction until the water surface in the chute rose to Elevation 227, when escape began through Bellhammer Slough, located as shown in Fig. 9. The elevation of the base of the levee being 208, there was then a depth of more than 19 ft. continually standing against this levee. The maximum width of the base of the levee was 308 ft., and the thickness of the embankment at Elevation 227, the surface of the back-water, was about 158 ft.

Under these conditions the front or river slope of the levee was dry, and practically no seepage occurred.

Bellhammer Slough was canalized and deepened, somewhat more than a year after the construction of the levee, and the elevation of the surface of the back-water standing against the levee was lowered about 6 ft., or to Elevation 221, where it now stands with scarcely any variation. Practically no seepage takes place, and the chute between the levee and Old River is being rapidly filled up by the sediment and deposit of the river.

As formerly stated, the levee in this vicinity is not thought to be of sufficient height to restrain the maximum flood of the Mississippi River, and during the present year it is proposed to raise the grade 3 ft. and to enlarge and strengthen the levee proportionally.

So far as the writer's experience and study extend, there appears to be no reason why dams constructed of earth should be limited to

any particular height, provided the slope and dimensions are sufficient. In the plan proposed by the author, the slope, base and dimensions certainly seem to be sufficient to withstand safely the head of 90 ft., the dam finishing 10 ft. above the level of the water impounded in the lake. The 4% slope, for material of that character, is no doubt much flatter than the slope of saturation. Probably the material in the foundation and for the dam at Bohio is more permeable than that generally obtained for the construction of levees in the Mississippi Valley, and the constant head in the one case might not be reasonably compared with the duration of the floods of the Mississippi River, though they stand sometimes as long as from 40 to 60 days within a few inches of the top of the levee; however, the incomparable dimensions proposed it seems would more than overcome the difference in conditions. It may be expected that such a dam and foundation will become less permeable as both the embankment and foundation settle and become more compact, and that seepage will decrease. Mr. Pharr.

It appears to the writer that it might be advisable to flatten the slope on the down-stream side of the high temporary earth dam, proposed in the third plan, from 1 on 2 to at least 1 on 3. This, however, would increase its cost considerably, which as proposed is nearly as much as the estimated cost for the permanent dam. The suggestion to undertake the construction of the permanent dam without the construction of the temporary dam is worthy of very serious consideration.

From a comparison of the Commission's plan with the third plan, if it may be considered that the slight seepage in the latter will be of no practical disadvantage, the very great difference in the cost, say $6 755 095 for the Commission's, and $2 025 675 for the third plan, should be a very strong inducement and justification for the adoption and construction of the latter. There is, of course, no material, out of which a dam can be constructed, of as great a permanence as earth.

Edwin Duryea, Jr., M. Am. Soc. C. E. (by letter).—Mr. Morison states that the criticism made on his plan is that "it permits seepage through the permeable sand and gravel in the lower part of the geological valley." Mr. Duryea.

His plan makes no attempt to prevent or diminish this seepage, and he contents himself with showing that the amount of water thus lost is relatively unimportant. It is just possible, however, that the actual amount of seepage might prove to be much larger than he believes can be the case, and it is this possibility which seems to be the objectionable feature of the plan. This objection will be removed if any practicable plan can be found which will prevent or diminish the amount of seepage. Such a plan will be most reassuring and most effective if it is of such a nature that it can be applied either before or

Mr. Duryea. after the construction of the dam, so as to be used only in case the seepage proves to be greater than is thought advisable, and if the plan is so flexible that it can be applied to as small or as great a degree as seems necessary, or can be resorted to at any subsequent period.

It is believed that a plan combining all these favorable features is that of forcing cement grout into the layer of permeable sand and gravel by means of pipes driven through the overlying materials and through the dam itself. The ordinary method of making wash-borings makes it practicable to reach the permeable layer quickly and cheaply, and the fact that the layer is permeable and allows water to rise in the pipes makes it certain that grout under pressure can be forced into it for some distance away from the pipe. The top and bottom of the layer of sand and gravel should be first located by the boring; then, beginning with the foot of pipe at the bottom of the layer, the grout should be pumped under pressure while the pipe is being raised by small increments to the top of the permeable layer. The pipe could then probably be withdrawn at once. Both the success attending the operation and the proper distance apart at which to place the holes could be ascertained either before or after the construction of the dam by observing the action of the grout in open pipes driven at various distances from the pipe being grouted. The efficiency of the plan in preventing seepage could be tested by completing a line of grouted holes across the valley and then testing the difference in height to which water would rise in pipes driven on the up-stream and on the down-stream sides of the line, or by completing two lines of grouted holes some distance apart up and down stream and then testing the height to which water would rise in pipes driven between the lines.

Any number of holes could be driven, but it seems that a double row arranged so that they form the apexes of equilateral triangles of 8-ft. sides should be quite effective. This would make a hole for each 4 ft. in width of the permeable layer. The width of this layer, on the sections shown, is nowhere as great as 300 ft., so that an allowance of 100 holes should be ample. There should be no difficulty in driving these holes and doing the grouting effectively for the sum of $500 per hole. This would make the cost of the 100 holes $50 000, or—allowing, say, 200 holes for safety—a cost of $100 000 for a plan which would remove the chief objection to Mr. Morison's proposed design. A means to positively control the seepage would be cheap even at twice this cost.

Mr. Morison's plan is very original in that it removes by the most radical means all danger from saturation. Past experience, however, has not shown this danger to be a very real one in ordinary earth dams of good design and construction. There seems to be no reason why his dam should cover such a large area, except that by this means the

volume of rock in the four rock-fill dams is perhaps kept down to a smaller amount than otherwise. His design is very economical, and, if more complete examinations show no worse conditions at the site than are now believed to exist, should probably be adopted in its original, or in some modified, form. Mr. Duryea.

The object in view by the Isthmian Canal Commission, however, was probably to present a plan which would meet the worst conditions that might be developed by more thorough examinations, and at the same time to assume as a preliminary estimate a cost so high that it would cover any reasonable plan which might be finally adopted. While all efforts should be made to use a more economical plan, such as that of Mr. Morison, it was certainly only prudent and conservative for the Commission to adopt for their purpose the much higher cost of their proposed design.

C. A. SUNDSTROM, M. Am. Soc. C. E. (by letter).—This paper is valuable and instructive, and if the United States Government decides to complete the Panama Canal, Mr. Morison's plan should be adopted in preference to any other, on account of increased utility, minimum cost, least amount of skilled labor required and completion in the shortest time. His plan offers another great advantage, in that it can be executed without the use of pneumatic caissons. Pneumatic caissons are very objectionable when they must be sunk to an unprecedented depth, in a tropical country, where the temperature is seldom, if ever, below 90°, and when, after the completion of the work, no better result has been obtained than if another, and less drastic, method had been adopted. Mr. Sundstrom.

The object of the Isthmian Canal Commission's plan, so far as the writer can see, is to reduce the seepage as much as possible, by constructing an earth dam, enclosing a core-wall, which is to be carried down to bed-rock by means of pneumatic caissons. Admitting the possibility of sinking caissons to the required depth, it must necessarily be a most difficult problem to fill the space between them with impervious material. It can be assumed, with reasonable certainty, that this can be done only within certain limits; that is to say, a depth will be reached, below which the spaces between the caissons must be left open and cause a seepage fully as great as that which may occur through the dam proposed by Mr. Morison.

The nature of the permeable strata, which cover the bed of the valley to a considerable depth, is the same at the site of the Isthmian Canal Commission's dam and the one proposed by Mr. Morison. Consequently, the same factors for calculating the velocity of the percolating water can be used in both cases, the length of the percolation being the only variable quantity. Mr. Morison's calculations show a velocity of 0.002 ft. per second under his dam, and a seepage of 40 cu. ft. per second. Assuming the length of the strata through which

Mr. Sundstrom. percolation will take place at the Isthmian Canal Commission's dam to be 500 ft., the velocity of the percolating water will be

$$V = \frac{1000 \times 90\ (90 + 10)}{500 \times 60}\ d^2$$

$$V = \quad 300\ d^2 \text{ m. per day, or}$$

$$V = 0.0117 \text{ ft. per second, when } d \text{ is assumed to be 1 mm.}$$

There are thirteen openings, each 4 ft. wide, giving a length of 52 ft. along the dam, through which seepage can pass without interruption. In order to produce a seepage of 40 cu. ft. per second, the depth, d, of the percolating strata will be found to be

$$52\ d \times 0.0117 = 40,$$

$$\text{giving } d = 65.7 \text{ ft.}$$

The elevation of the bottom of the core-wall is — 128. Consequently, the depth to which the percolation must be interrupted will be — 128 + 65.7 = — 62.3.

This shows, beyond a doubt, that in order to obtain the same result as Mr. Morison, the Isthmian Canal Commission, after the caissons have been put in place and the core-wall has been constructed, have a Herculean task ahead of them. If they succeed in solving the problem that far, they will have a structure which will cost $4 700 000 more than Mr. Morison's plan, will require a great amount of skilled labor, and will consume considerably more time in its construction.

NATHANIEL EDWARDS RUSSELL, M. Am. Soc. C. E.*

DIED JANUARY 14TH, 1902.

Nathaniel Edwards Russell, son of Charles P. and Louisa (Richardson) Russell, was born at Washington, D. C., on February 24th, 1848. His father was a clergyman, a personal friend of Abraham Lincoln, and delivered the sermon at the funeral of the murdered President.

Mr. Russell's education began in the schools of Washington, and he then took a practical course in mechanical engineering, serving his time in machine shops there.

In 1867 he entered the Rensselaer Polytechnic Institute, and was graduated in 1870, taking the degree of C. E.

His first position was that of Civil Assistant Engineer under General G. K. Warren, Corps of Engineers, U. S. A., his work being upon surveys and improvement of rivers and harbors in New England. Later, he was transferred to the Northwest, in the same service, and, as Assistant Engineer, was in charge of the work of establishing slackwater navigation on the Fox River. He also made numerous surveys. From May to November, 1871, he was in charge of the construction of a pile pier in the harbor at Menominee, Michigan. From November, 1871, to May, 1872, he was in the United States Engineers' office at Chicago, Illinois. From May to November, 1872, he was Assistant United States Engineer in charge of the lower section of the Wisconsin River improvement, and from the latter date until July, 1875, he was in charge of the detailed surveys and the construction of the upper and lower sections of the Fox River improvement.

From September, 1875, to February, 1876, Mr. Russell was Assistant Engineer on the construction of the Albany and Greenbush Bridge. From July, 1876, to January, 1882, he was with the Wiley and Russell Manufacturing Company of Greenfield, Massachusetts, designing and superintending the enlargement of their plant.

Mr. Russell was General Manager of the Alleghany Coal and Iron Company, of Richmond, Virginia, from January, 1882, to March, 1883, and President of that company from the latter date until July, 1885, and at the same time General Manager of the Henrico Coal Company, of Richmond.

He practiced afterward as a consulting engineer, with headquarters at Lansingburg, New York, designing and erecting bridges and roofs, among the latter being that of Harmanus Bleeker Hall, at Albany, New York. He was also in charge of the construction of the bridge

* Memoir prepared by A. J. Swift, C. E.

connecting the tracks of the Utica, Clinton and Binghamton and the Utica and Black River Railroads, at Utica, New York.

For a short time he was Superintendent of the works of the American Graphophone Company.

From 1891 to 1894 he was General Manager of the Walter A. Wood Manufacturing Company, at Hoosick Falls, Massachusetts, and, later, resumed his practice as consulting engineer.

On July 1st, 1874, Mr. Russell married Miss Lucy Coleman Flack, daughter of Mr. David H. Flack, of Lansingburg, New York.

His death occurred at Lansingburg, New York, on January 14th, 1902, and resulted from a fall in alighting from an electric car in the summer of 1891, his senses of smell and taste remaining much impaired after his recovery from a severe illness following this accident. He died after a few moments of intense suffering, followed by several hours of unconsciousness. He leaves a widow and one daughter.

It is difficult to express in words the affection and esteem which were felt for Mr. Russell by every one privileged to know him. To him his friends were truly "knit with hooks of steel," and the announcement of his death made the world seem smaller to each and all of them.

He felt no wish to become conspicuous, professionally or otherwise, but shrank from notice, rather than courted it. He always undervalued his own ability, and worked zealously, intelligently and successfully from love of the profession which he adorned. No thought or action below the highest standard of honor, kindliness, and generosity was possible to him, and every individual who knew him will endorse the absolute truth of these words. He deserved, if ever man did, to rank as a type of the dignified Christian gentleman, able and experienced engineer, man of catholic and cultivated taste and reading, devoted husband and father, and staunch friend; and, as a rare combination of all these qualities, his sorrowing friends will always remember him. Every community in which he has lived has benefited by his life and is a loser by his death.

Mr. Russell was elected a Member of the American Society of Civil Engineers on October 3d, 1888.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXVIII. No. 4.

APRIL, 1902.

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1902.

American Society of Civil Engineers.

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Special Committees.

ON ANALYSIS OF IRON AND STEEL:—Sub-Committee of the American Society of Civil Engineers (of the International Committee on Standards for the Analysis of Iron and Steel, of which Prof. J. W. Langley is Chairman)—Charles B. Dudley, William Metcalf. Thomas Rodd.

ON UNITS OF MEASUREMENT:—George M. Bond, William M. Black, R. E. McMath, Charles B. Dudley, Alexander C. Humphreys.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, George F. Swain, Alfred Noble, W. B. W. Howe, Louis C. Sabin, S. B. Newberry, Clifford Richardson, Richard L. Humphrey, F. H. Lewis.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK

TELEPHONE NUMBER, - - - - 538 Columbus.
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Vol. XXVIII. APRIL, 1902. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

April 2d, 1902.—The meeting was called to order at 8.45 P. M., James Owen in the chair; Charles Warren Hunt, Secretary; and present, also, 81 members and 5 guests.

The minutes of the meetings of March 5th and 19th were approved as printed in the *Proceedings* for March, 1902.

A paper by Marsden Manson, M. Am. Soc. C. E., entitled "A Brief History of Road Conditions and Legislation in California," was presented by the Secretary and discussed by Messrs. James Owen and George W. Tillson.

A second paper, by Charles C. Wentworth, M. Am. Soc. C. E., entitled "Line and Surface for Railway Curves," was presented by the Secretary, who also read a communication on the subject from James K. Geddes, M. Am. Soc. C. E.

Ballots for membership were canvassed and the following candidates were elected:

As Members.

Charles Aldo Alderman, Columbus, Ohio.
Edward Richard Cary, Troy, N. Y.
Charles Frederick Dunham, Sierra Mojada, Mexico.
Felix Freyhold, Washington, D. C.
John Venable Hanna, Springfield, Mo.
John Lewis Howard, Boston, Mass.
William Henry Luster, Jr., Elizabeth, N. J.
George Sergeant, Jr., Brooklyn, N. Y.

As Associate Members.

George Washington Armitage, Havana, Cuba.
Harold Bedford Atkins, New York City.
John Walker Barriger, Jr., Kansas City, Mo.
Murray Blanchard, Detroit, Mich.
Benjamin Franklin Cresson, Jr., New York City.
Frederick Harold Fay, Boston, Mass.
Gustavus Adolphus Gessner, Jr., Toledo, Ohio.
Charles Gilman Hyde, Philadelphia, Pa.
George Washington Lilly, Columbus, Ohio.
Harry John McDargh, Dayton, Ohio.
Walter Edwin Noble, Fall River, Mass.
Herman Schneider, South Bethlehem, Pa.
Charles Albert Slayton, Wapanucka, Ind. T.
Perley Egbert Stevens, Philadelphia, Pa.
Thomas Hollis Wiggin, Jersey City, N. J.
Henry Felix Wilson, Jr., Birmingham, Ala.

The Secretary announced the election of the following candidates by the Board of Direction on April 1st, 1902:

As Associate.

Franklin Lincoln Gaines, Grand Rapids, Mich.

As Juniors.

Frank Rahn Shunk Layng, Pittsburg, Pa.
Hans Carl Thomas Toensfeldt, St. Louis, Mo.
John George Ullmann, Buffalo, N. Y.
George Littleton Warner, Washington, D. C.

The Secretary announced the subjects, adopted by the Publication Committee, for topical discussion at the Annual Convention.*

The Secretary announced the death of NATHANIEL CHENEY, elected Fellow July 21st, 1870; died June 29th, 1901.

The Secretary announced the appointment, by the Board of Direction, of the following Special Committee on Rail Sections:

G. BOUSCAREN, *Chairman;*

C. W. BUCHHOLZ,	H. G. PROUT,
S. M. FELTON,	JOSEPH T. RICHARDS,
ROBERT W. HUNT,	PERCIVAL ROBERTS, Jr.,
JOHN D. ISAACS,	GEORGE E. THACKRAY,
RICHARD MONTFORT,	EDMUND K. TURNER,

WILLIAM R. WEBSTER.

Adjourned.

April 16th, 1902.—The meeting was called to order at 8.40 P. M., Emil Kuichling, Director, Am. Soc. C. E., in the chair; Charles Warren Hunt, Secretary; and present, also, 126 members and 11 guests.

A paper by Archibald R. Eldridge, M. Am. Soc. C. E., entitled "Is it Unprofessional for an Engineer to be a Patentee?" was presented by the Secretary and discussed by Messrs. Samuel Whinery and James Owen.

A second paper, by Joseph Mayer, M. Am. Soc. C. E., entitled "The Stiffening System of Long-Span Suspension Bridges for Railway Trains," was read by title and discussed by Messrs. L. S. Moisseiff, H. A. La Chicotte, W. Hildenbrand and L. L. Buck.

The Secretary announced the leading features of the programme for the Annual Convention.

The Secretary announced the death of EMILIO DEL MONTE, elected Member December 4th, 1895; died March 20th, 1902.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

April 1, 1902.—8.20 P. M.—Vice-President Schneider in the chair; Charles Warren Hunt, Secretary, and present, also, Messrs. Briggs, Buck, Croes, Endicott, Knap, Pegram, Seaman and Wilgus.

Action was taken completing the Special Committee to report on Rail Sections.

Applications were considered, and various matters of business detail transacted.

One candidate for Associate and four for Junior were elected.†

Adjourned.

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* See page 127.

† See page 124.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, May 7th, 1902.—8.30 P. M.—At this meeting, ballots for membership will be canvassed, and a paper by George S. Webster and Samuel Tobias Wagner, Members, Am. Soc. C. E., entitled "The Pennsylvania Avenue Subway and Tunnel, Philadelphia, Pa.," will be presented for discussion.

This paper was printed in the *Proceedings* for March, 1902.

Wednesday, June 4th, 1902.—8.30 P. M.—At this meeting, ballots for membership will be canvassed, and a paper by George L. Dillman, M. Am. Soc. C. E., entitled "A Proposed New Type of Masonry Dam," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

Wednesday, September 3d, 1902.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper by R. C. McCalla, M. Am. Soc. C. E., entitled "Improvement of the Black Warrior, Warrior and Tombigbee Rivers, in Alabama," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL CONVENTION OF 1902.

The Thirty-fourth Annual Convention of the Society will be held at Washington, D. C., beginning on Tuesday, May 20th, 1902.

A programme has been arranged and its general features have been indicated in a circular which has been sent to all members.

The general arrangements for the Convention are in the hands of a Committee of the Board of Direction, consisting of the following:

Mordicai T. Endicott,
George H. Pegram, Chas. Warren Hunt.

The following Local Committee of Arrangements has been appointed by the Board of Direction:

George W. Melville. *Chairman;*
John Biddle, C. B. Hunt,
William M. Black, D. E. McComb,
D. S. Carll, Alexander Mackenzie,
Bernard R. Green, Alexander M. Miller,
H. M. Wilson.

TOPICS FOR INFORMAL DISCUSSION.

The following topics have been selected for discussion:

Topic No. 1. "In contract work, either public or private, is it preferable to make separate contracts for the different branches of trades involved, or to combine all under one general contract?"

Topic No. 2. "Is it possible and desirable to keep accounts of work in progress in such a manner as to ascertain unit costs on each class of work?"

Topic No. 3. "Is steel susceptible of being made as permanent a building material as masonry?"

Topic No. 4. "In view of the numerous disasters caused by the contracting of channels, or the damming of small streams, should non-navigable streams be under the control of the National Government?"

Topic No. 5. "Should the National Government undertake the construction and operation of irrigation works?"

Topic No. 6. "Should Engineering Practice be regulated by a code of ethics? If so, how can such a code be established?"

ACCESSIONS TO THE LIBRARY.

DONATIONS.*

(From March 13th to April 8th, 1902.)

COMPRESSED AIR.

Its Production, Uses and Applications, comprising the Physical Properties of Air from a Vacuum to its Liquid State, its Thermo-Dynamics, Compression, Transmission and Uses as a Motive Power in the Operation of Stationary and Portable Machinery, in Mining, Air Tools, Air Lifts, Pumping of Water, Acids and Oils; the Air Blast for Cleaning and Painting, the Sand Blast and its Work, and the Numerous Appliances in which Compressed Air is a Most Convenient and Economical Transmitter of Power for Mechanical Work, Railway Propulsion, Refrigeration and the Various Uses to which Compressed Air has been Applied. By Gardner D. Hiscox, M. E. Cloth, 10 x 7 ins., 822 pp., portrait, illus. New York, Norman W. Henley & Co., 1901. $5.00.

The author states in the preface that the practical application of compressed air for doing mechanical work is of so recent date that the design and construction of any of the most useful machines operated by compressed air rest upon empirical rather than scientific formulas. It is one of the objects of the present volume to make available the ascertained facts of experimental research in atmospheric phenomena, and, so far as possible, the fundamental basis upon which such ascertained facts securely rest. In addition to the consideration of the properties of air when simply compressed above the ordinary pressure of the atmosphere, the work includes also a consideration of the properties of air below atmospheric pressure. A large number of illustrations are given to show the salient features of the latest and best designs, including portable machines and individual and special tools for lessening manual labor and increasing the output of work. The work includes a consideration of the hygienic problems involved in caisson work, and the use of compressed air for refrigerating purposes with the physical and thermo-dynamic problems connected therewith.

THE EARNING POWER OF RAILROADS.

With Tables Showing Facts as to Earnings, Capitalization, Mileage, etc., of One Hundred Railroads in the United States and Canada. By Floyd W. Mundy. Cloth, 8 x 5½ ins., 190 pp. New York, Floyd W. Mundy, 1902. $2.00.

In the introductory remarks it is stated that this volume treats alone and in the most simple and tentative manner of the earning power of railroads, and deals not at all with the traffic resources and the financial and physical condition. It is intended to be a helpful guide to investors. It consists of a number of short chapters on Income Account, Operating Expenses, Maintenance Expenses, Maintenance of Way, Maintenance of Equipment, Conducting Transportation and General Expenses, The Operating Ratio, Fixed Charges, and Stock Outstanding in its Relation to Earning Power, followed by tables and notes relating to specific railroads in the United States and Canada.

THE BLOCK SYSTEM OF SIGNALING ON AMERICAN RAILROADS.

The Methods and Appliances Used in Manual and Automatic Block Signaling, also Descriptions of Hand Operated and Power Operated Interlocking Machines. By Braman B. Adams. Cloth, 9 x 6 ins., 234 pp., illus. New York, *The Railroad Gazette*, 1901. $2.00.

This book is a revised edition of "American Practice in Block Signaling," issued ten years ago. The matter has been entirely rewritten. Nearly every mechanical or electrical device described in the former work has been improved or superseded, and the bulk of the book is taken up with the numerous modifications and improvements which have been made since 1890. The aim has been to treat the subject from a practical standpoint; to show well-approved practice, rather than ideals or experiments. History is touched upon only incidentally. There have been added brief descriptions of the

* Unless otherwise specified, books in this list have been donated to the Library by the Publisher.

principal types of interlocking machines used in America. In these descriptions, as in those of the mechanical features of block signaling, the purpose has been to show the methods of working, rather than details of material or construction. The Contents are: The Telegraph Block System, Pennsylvania R. R.; The Telegraph Block System, Erie R. R., Chicago, Burlington & Quincy R. R.; The Telegraph Block System on Single Track, Chicago, Milwaukee & St. Paul Ry.; Single-Track Blocking, Erie R. R., Wabash R. R., Atchison, Topeka & Santa Fé Ry.; The Controlled Manual or "Lock-and-Block" System, New York, New Haven & Hartford R. R.; Controlled Manual. The Electric Train Staff; Automatic Block Signals—Clock-Work Apparatus, Enclosed Disk Signals; Automatic Block Signals on Single-Track, Cincinnati, New Orleans & Texas Pacific Ry.; Electro-Pneumatic Automatic Block Signals; Automatic Block Signals—The Electric Semaphore; Three-Position Automatic Block Signals, Pittsburgh, Fort Wayne & Chicago Ry.; Conclusions, Statistics; The Saxby and Farmer Interlocking Machine; The Johnson Interlocking Machine; The Westinghouse Electro-Pneumatic Machine; The Low-Pressure Pneumatic Machine; The Taylor Electric Machine. There is an index of four pages.

PRACTICAL CALCULATION OF DYNAMO-ELECTRIC MACHINES.

A Manual for Electrical and Mechanical Engineers and a Text-Book for Students of Electrical Engineering, Continuous Current Machinery. By Alfred E. Wiener, M. A. I. E. E. Second Edition, Revised and Enlarged. Cloth, 9½ x 6½ ins., 36 + 727 pp., illus. New York, *Electrical World and Engineer*, 1902. $3.00.

It has been the aim of the author in preparing this volume to develop an entirely practical treatise on dynamo-calculation, the treatment of the subject being based upon results obtained in practice and therefore giving such practical experience. There are more than a hundred original tables and nearly five hundred formulas derived from the data and tests of over two hundred modern dynamos of American as well as English make. Although intended as a text-book for students and a manual for practical dynamo designers, it is believed that any one possessing a fundamental knowledge of arithmetic and algebra will be able, by means of this work, successfully to calculate and design any kind of a continuous-current dynamo. The formulas are so prepared that the results are obtained in inches, feet, pounds, etc., but the tables are given both for the English and metric systems. The Contents are: Physical Principles of Dynamo-Electric Machines; Calculation of Armature; Calculation of Magnetic Flux; Dimensions of Field-Magnet Frame; Calculation of Magnetizing Force; Calculation of Magnet Winding; Efficiency of Generators and Motors, Designing of a Number of Dynamos of Same Type, Calculation of Electric Motors, Unipolar Dynamos, Motor-Generators, etc., and Dynamo Graphics; Practical Examples of Dynamo Calculation; Tables of Dimensions of Modern Dynamos; Wire Tables and Winding Data; Localization and Remedy of Troubles in Dynamos and Motors in Operation. There is an index of twenty-three pages.

ELECTRIC GAS LIGHTING.

How to Install Electric Gas Igniting Apparatus Including the Jump Spark and Multiple Systems for Use in Houses, Churches, Theatres, Halls, Schools, Stores or any Large Buildings; also the Care and Selection of Suitable Batteries; Wiring and Repairs. By H. S. Norrie (Norman H. Schneider). Cloth, 6½ x 5 ins., 8 + 101 pp., illus. New York, Spon & Chamberlain, 1901. $0.50.

The preface states that the object of this book is to enable any one possessing ordinary mechanical ability to construct much of the apparatus used for igniting gas by electricity, or at least to successfully erect it and keep it in operation, as it requires no very complicated devices, nor does it necessitate a deep knowledge of electrical matters for its installation. The Contents are: Introductory Remarks; Multiple Gas Lighting; Connections and Wiring; Primary Coils and Safety Devices; Lighting of Large Buildings; How to Select Batteries for Gas Lighting. There is an index of three pages.

WATER-TUBE BOILERS.

Based on a Short Course of Lectures Delivered at University College, London. By Leslie S. Robertson, M. Inst. C. E. Cloth, 9 x 6 ins., 15 + 213 pp., illus. New York, D. Van Nostrand Company, 1901. $3.00.

The author states in the preface that the issue of this book in its present form is due to the want of a short practical work of reference on water-tube boilers for students and engineers; that it has retained, more or less, the form of the lectures, but that they have been revised and adapted as far as possible to their present purpose. No attempt has been made to deal with the subject exhaustively or in great detail, the scope hav-

ing been confined to the following topics: 1. An historical description of the better-known types of tubulous boilers, from the early attempts to the present day. 2. The consideration of the general principles underlying the construction of steam boilers, but dealing with them only in so far as they immediately concern water-tube boilers. 3. A discussion of the principles underlying the circulation of the water and the hot gases. 4. Short description of the better-known types of water-tube boilers. 5. Boiler mountings and accessories. 6. Weight and space occupied. 7. Advantages and disadvantages of this type of boiler. An appendix gives the Interim Report of the Committee, appointed by the Lords Commissioners of the Admiralty, to consider certain questions respecting modern types of boilers for naval purposes. There is an index of nine pages.

SOME DETAILS OF WATER-WORKS CONSTRUCTION.

By William R. Billings. Third Edition. Cloth, 9 x 6 ins., 96 pp., illus. New York, *The Engineering Record*, 1898. $2.00.

The present volume consists of a series of articles which were originally published in *The Engineering Record*. The writer states that he has endeavored to be brief and practical, having especially in mind those who have had little or no experience in actual construction and who desire information and suggestion upon the simplest details. The headings of chapters are: The Distributing System; Field Work; Trenching and Pipe-Laying; Pipe-Laying and Joint-Making; Hydrants, Gates, and Specials; Service-Pipes; Service-Pipes and Meters; Notes on the Construction of about Two Miles of 16-Inch Water-Main; Tables of Cost.

FURNACE DRAFT.

Its Production by Mechanical Methods. By William Wallace Christie, M. Am. Soc. M. E. Cloth, 6 x 4 ins., 44 pp., illus. Published by the Author, Paterson, N. J., 1901. $0.50.

In presenting this monograph to the public the author has made no claim for its completeness nor for his infallibility, but only that he has given to the reader some facts concerning mechanical draft in a convenient form for ready reference. Some of the material has already appeared in the *Engineering Magazine*. There is an index of two pages.

PLANE SURVEYING.

A Text and Reference Book for the Use of Students in Engineering and for Engineers Generally. By Paul C. Nugent. Cloth, 9 x 6 ins., 16 + 577 pp., 6 plates, illus. New York, John Wiley & Sons, 1902. $3.50.

The arrangement of the topics in this work is in the order in which it has seemed easiest to teach them, due regard being had to completeness under each head, rather than by classification under the subdivisions of the subject. Special attention is called to the treatment of the adjustments of instruments by the methods of descriptive geometry, the chapter on telescopes, and the forms for systematic arrangement of computations. The Contents are: Introduction; Linear Measuring Instruments and Range Poles; Chain Surveying; Compass and General Surveying; The Telescopes of Surveying Instruments; Leveling; Transit Surveying; The Planimeter and the Slide Rule; Topographical Surveying; Hydrographic Surveying; Mine Surveying; The Solar Instruments; The U. S. Public Lands.—Resurveys; Problems; The Cyclotomic Transit; The Restoration of Lost or Obliterated Corners and Subdivision of Sections; Photo-topographic Methods and Instruments. There is an index of five pages.

SEWAGE AND THE BACTERIAL PURIFICATION OF SEWAGE.

By Samuel Rideal. Second Edition. Cloth, 9 x 6 ins., 2 + 308 pp., illus. New York, John Wiley & Sons, 1901. $3.50.

The author has endeavored to treat this subject from the view point that all schemes for the purification of sewage by bacterial processes must be based upon the theory of the bacterial changes, so far as they have been studied. In preparing the second edition, the entire work has been revised, and much further knowledge added, both in theory and practice, of the remarkable development of bacterial treatment of sewage. Parts of the earlier edition have been condensed to make room for fresh matter, as the aim has been to convey in a small space as much information as possible. The Contents are: Characters of Sewage, and Primary Methods of Disposal; Chemical Analyses of Sewage and Effluents; Bacteria Occurring in Sewage; Chemical Changes Produced by Bacteria; Irrigation and Sewage Farms; Subsidence and Chemical Precipitation; Sterilization; Bacterial Purification; Agricultural Value of Bacterial Effluents; Distribution and Distributors; Trade Effluents. There is an index of twelve pages.

REVIEW AND TEXT OF THE AMERICAN STANDARD SPECIFICATIONS FOR STEEL.

Adopted in August, 1901, by the American Section of the International Association for Testing Materials. By Albert Ladd Colby, Member of Committee No. 1 of American Section of the I. A. T. M. Second Edition, Rewritten and Containing the Revised Text of the Standard Specifications. Cloth, 7 x 5 ins., 103 pp. Easton, Pa., The Chemical Publishing Company, 1902. $1.10. (Donated by the Author.)

The introduction states that in drawing up these standard specifications the Committee was conservative, and included, in the main, only such requirements as has been proved in practice to be of value or essential in determining whether or not the material is suited for the purpose intended. The specifications were adopted as representing the American practice of to-day. They are not intended to cover every specific purpose, but it is believed that they will serve for the majority of uses to which steel is applied, and that they can be modified to suit particular requirements without departing materially from the standard form and practice recommended. In addition to the text of the specifications, the work contains the reasons governing the Committee in its decisions.

WATER AND WATER SUPPLIES.

By John C. Thresh. Third Edition, Revised and Enlarged. Cloth, 8 x 5 ins., 15 + 527 pp., illus. Philadelphia, P. Blakiston's Son & Co., 1901. $2 00.

The main object of this work is to place within the reach of those interested in public health the information requisite for forming an opinion as to whether any supply or proposed supply of water is sufficiently wholesome and abundant, and whether the cost is reasonable. It does not pretend to be a treatise on Engineering, yet it is hoped that it contains sufficient detail to enable anyone to consider intelligently any scheme for supplying a community with water. The author has embodied in various chapters the experience gained in large rural districts where his schemes have been carried to a successful completion. The last chapter gives a brief *résumé* of the law relating to water supplies. The chapter headings are: Water, Its Composition, Properties, etc.; Rain and Rain Water; Surface Water; Subsoil Water; Natural Spring Water; Deep-Well Waters; River Water; Quality of Drinking Waters; Impure Water and Its Effect upon Health; The Interpretation of Water Analyses; The Pollution of Drinking Water; The Self-Purification of Rivers; The Purification of Water on the Large Scale; Domestic Purification; The Softening of Hard Water; Quantity of Water Required for Domestic and Other Purposes; Selection of Sources of Water Supply and Amount Available from Different Sources; The Protection of Underground Water Supplies; The Protection of Surface-Water Supplies; Wells and Their Construction; Pumps and Pumping Machinery; The Storage of Water; The Distribution of Water; The Law Relating to Water Supplies; Rural and Village Water Supplies; Water Charges. There is an index of twenty-nine pages.

SHOP AND ROAD TESTING OF DYNAMOS AND MOTORS.

A Practical Manual for the Testing Floor, the Car Barn and the Road. By Eugene C. Parham and John C. Shedd. Cloth, 8 x 6 ins., 12 + 627 pp., illus. New York, *Electrical World and Engineer*, 1901. $2.50.

This work has a two-fold object: I. To give a complete theory of the commercial testing floor, so far as it relates to direct-current machines, and of the applications of theory to practice. II. To meet the demand on the part of operating companies for a manual that shall enable them to do their own repair work and consequent testing. The first part of the book is devoted to such fundamental and preliminary conceptions as are needed to help those unacquainted with the general theory. The second part treats of the testing and use of instruments. The third part takes up in detail the tests of dynamos and motors. All examples and illustrations are taken from personal experience. In this, the second edition, the scope of the work has been extended to include street-car equipment and operation. The authors have endeavored in this to be strictly practical and at the same time to aid the reader in obtaining a comprehensive grasp of the principles involved. The headings of chapters are: Elements of the Dynamo; Elements of the Motor; Ohm's Law; Measurement of Current; Measurement of Electromotive Force; Measurement of Resistance; Measurement of Insulation; The Series Machine; Shunt and Compound-Wound Machine; The Compound-Wound Machine—General Tests; Compounding; Miscellaneous Tests; Grounds on the Line; Motor Testing; Installation Car Equipment Tests; Car Equipment Tests. There is an index of seven pages.

The following gifts have also been received:

Alexandria, Ind., City Civ. Engr. 1 specif.
Am. Soc. of Mech. Engrs. 1 pam.
Assoc. Amicale des Anciens Élèves de l'École Centrale des Arts et Manufactures. 1 vol.
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Journal of Gas Lighting. 30 nos.
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Lansing, E. Ten Eyck. 1 pam.
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BY PURCHASE.

Outlines of Electrochemistry. By Harry C. Jones. New York, The Electrical Review Publishing Co., D. Van Nostrand Company, 1901.

Practical Marine Engineering for Marine Engineers and Students, with Aids for Applicants for Marine Engineers' Licenses. By William F. Durand. New York, Marine Engineering, Inc., 1901.

Machines à Vapeur et Machines Thermiques Diverses. Par J. Dejust. Paris, Ch. Dunod, 1899.

Directory to the Iron and Steel Works of the United States, Embracing a Full List of the Blast Furnaces, Rolling Mills, Steel Works, Rail Mills, Structural Mills, Plate and Sheet Mills, Steel Casting Works, Tinplate Works, Wire-Rod Mills, Cut-Nail Works, Wire-Nail Works, and Forges and Bloomaries, with Full Particulars of Equipment, Products, Ownership, Officers, and All Recent Consolidations, to Which is Added a Complete List of the Iron and Steel Works of Canada. Compiled and Published by The American Iron and Steel Association. Fifteenth Edition. Corrected to December 31, 1901. Philadelphia, The American Iron and Steel Association, 1901.

Statistics of the American and Foreign Iron Trades for 1897, 1899 and 1900; Annual Statistical Report of the American Iron and Steel Association, Containing Complete Statistics of the Iron and Steel Industries of the United States for 1897, '99 and 1900 and Preceding Years; also Statistics of the Iron Ore, Coal, Coke, and Shipbuilding Industries of the United States, and of Imports and Exports of Iron and Steel and Iron Ore. 3 vols. Philadelphia, The Iron and Steel Association, 1898–1900.

The Anthracite Coal Industry, a Study of the Economic Condition and Relations of the Coöperative Forces in the Development of the Anthracite Coal Industry of Pennsylvania. By Peter Roberts. With an Introduction by W. G. Sumner. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1901.

A New Pronouncing Dictionary of the Spanish and English Languages. Compiled by Mariano Velázquez de la Cadena. Revised and Enlarged by Edward Gray and Juan L. Iribas. First Part: Spanish-English. New York, D. Appleton & Company, 1901.

Handbuch der Ingenieurwissenschaften. Vol. 1, pt. 5. Leipzig, Wilhelm Engelmann, 1902.

United States Official Postal Guide, January, 1902. Philadelphia, George F. Lasher, 1902.

International Railway Congress. Sixth Session. Paris, September, 1900. Proceedings (English Edition.) Vol. 1-2. Brussels, P. Weissenbruch, 1901.

Beitrag, zum derzeitigen Stande der Abwasserreinigungsfrage mit besonderer Berücksichtigung der biologischen Reinigungsverfahren. Von *Prof. Dr.* Dunbar, *Dr.* K. Thumm. München und Berlin, R. Oldenbourg, 1902.

SUMMARY OF ACCESSIONS.

March 13th to April 8th, 1902.

Donations (including 3 duplicates and 57 numbers, completing volumes of periodicals)	356
By purchase	12
Total	368

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ADDITIONS.

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DEATHS.

CHENEY, NATHANIEL ....Elected Fellow June 21st, 1870; died June 29th, 1901.

DEL MONTE, EMILIO ....Elected Member Dec. 4th, 1895; died March 20th, 1902.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(March 13th to April 8th, 1902.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Eng., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Can.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Institute, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 30c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 35c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
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(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England.
(22) *Iron and Coal Trades Review*, London, England.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, 75c.
(29) *Journal*, Society of Arts, London England.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des Ecôle Spéciales de Gand*, Brussels, Belgium.
(32) *Memoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*. Paris, France.
(35) *Nouvelles Annales de la Construction*. Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Eng., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 75c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 10c.
(47) *Mechanical Engineer*, Manchester, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Institute of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 10c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.

Bridge.

Formulæ for the Weights and Economic Depths of Plate Girders. Alfred Fyson, M. Inst. C. E. (11) Serial beginning Mar. 14.
A New Type of Concrete-Steel Arch Culvert or Bridge.* Daniel B. Luten. (18) Mar. 15.
The Interprovincial Cantilever Bridge at Ottawa, Ont.* (18) Mar. 15.
Plate Girder Webs. T. Graham Gribble, Assoc. M. Inst. C. E. (62) Mar. 20.
The New Ferry Bridge Across the Ship Canal at Duluth, Minn.* W. B. Patton. (13) Mar. 20.
The Highland Park Bridge, Pittsburg.* (14) Mar. 22.
Iron and Steel Structures. (From Committee Report, Amer. Ry. Eng. and M. of W. Assoc.) (18) Mar. 22.
High Concrete Piers for Railway Bridge Across Stone's River; Tennessee Central Ry.* (13) Mar. 27.
Concrete-Steel Arch Y-Bridge at Zanesville, O.* (13) Mar. 27.
The Chesapeake & Ohio Railroad Bridge at Richmond, Va.* (14) Mar. 29.
Notes sur la Construction du Viaduc du Viaur (Ligne de Carmaux à Rodey). M. Théry. (43) 3e Trimestre, 1901.
Conférence sur l'Experimentation des Ponts. M. Rabut. (43) 3e Trimestre, 1901.

Electrical.

The Construction of High Tension Central Station Switch-Glass. Henry W. Clothier, A. M. I. C. E. (Paper read before Inst. of Elec. Engrs., Manchester Section.) (26) Serial beginning Mar. 7.
Electric Power in the Manufacture of Shale Oil. (11) Mar. 14.
Frankfort Electricity Works.* (26) Mar. 14.
The Transmission System of the Compania Explotadora de San Ildefonso of the City of Mexico. (27) Serial beginning Mar. 15.
Efficiencies of Electric Cranes. (47) Mar. 15.
Electric Furnaces.* Bertram Blount. (Paper read before Manchester Section, Inst. Elec. Engrs.) (47) Mar. 15.
Wireless Telegraphy and Submarine Cables.* E. Guarini. (26) Serial beginning Mar. 21.
Bristol Electricity Works Extensions.* (26) Mar. 21.
Synchronous Motor Stability and Overload Capacity Curves. F. G. Baum. (27) Mar. 29.
Modern Electric Hoists and Cranes for Steel Works.* Dr. A. Krebs. (27) Mar. 29.
High Tension Electric Power Transmission.* George H. Gibson. (9) Apr.
Electric Energy Direct from Coal. J. Wright. (10) Apr.
Electric Storage Batteries. Arvid Reuterdahl. (10) Apr.
Parallel Operation of Alternators. Paul M. Lincoln. (3) Apr.
Electrochemical Polarization. G. J. Reed. (3) Apr.
A New Telephone Exchange in London.* (27) Apr. 5.
The Telephone in Wireless Telegraphy.* Emile Guarini. (27) Serial beginning Apr. 5.
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The Acker Electrolytic Alkali Process.* Clinton Paul Townsend. (27) Apr. 5.
The Independent Telephone Movement in Philadelphia.* (27) Apr. 5.
Les Secteurs de Distribution d'Électricité à Paris. Charles Marquet. (33) Serial beginning Mar. 22.

Marine.

Repairs to the Battleship *Oregon* at the Puget Sound Navy Yard.* (13) Mar. 18.
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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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Vol. XXVIII. APRIL, 1902. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

A PROPOSED NEW TYPE OF MASONRY DAM.

By George L. Dillman, M. Am. Soc. C. E.

To be Presented June 4th, 1902.

Strains in masonry dams have been analyzed by many investigators, so that definite requirements must be fulfilled before any proposed plan will receive consideration by the engineering profession. These may be stated briefly as follows :

1.—The dam must not overturn.

2.—The dam must not sustain an intensity of pressure beyond a safe and known limit.

3.—The dam must not slide on its base.

4.—No possible condition must develop tension in any part of the masonry.

It is the purpose of this article to suggest a new type of dam, according to these requirements, so far as they are reasonable, which will contain less masonry, for the same factors of safety, than any of the recognized "standard types."

The theory on which all investigators, from Sazilly to Wegmann, have based their profile sections is that, the stability of one section being proven, a uniform construction to that section would insure the stability of the whole. While this is unquestionably true, it does not

Note.—These papers are issued before the date set for presentation and discussion Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

follow that uniformity of section is necessary to stability. The writer will strive to show in this article that a more stable and economical dam can be built in the form of a buttressed wall, properly proportioned; or, the proposed type can be considered as a series of short, arched dams between piers shaped so as to be economical of material, and with sufficient factors of safety.

There is a principle in hydraulic construction which is too frequently ignored. It is, to construct one water-tight surface and build the remainder of the structure to support that surface. The attempt to stop leakage that has gotten through such a surface is frequently a cause of failure. If there is leakage or seepage through the upper face of a dam of any of the standard types, the formulas for stability are founded on error. The upper face must be tight, or the computed line of pressure, when the reservoir is full, is wrong. John D. Van Buren, M. Am. Soc. C. E.. recognized that seepage under the foundation would also upset the calculations of the analysts of the "standard type" dams, but proposed as a remedy another uniform-section type, very much heavier than any of them.*

While these criticisms also apply to the proposed type, the comparatively thin parts allow this seepage through the upper face to escape before penetration beyond a known point in the masonry, and the seepage under the foundation can escape between the buttresses without exerting a dangerous upward pressure on the base. In either case, the point of leakage can be more easily located.

The writer does not want to be understood as advocating leaky dams; but, as most of the dams in the world are leaky, the possibility of leaks should not be neglected, and their possible effects should be reckoned with.

Infinite variety may result in the application of these principles. One computation will be made here to show the method and the simplicity of the mathematics involved. The solution of no equations above simple ones is necessary. The portions between buttresses will be made parabolic in horizontal section, which will avoid all re-entrant angles, introduce the strongest arch to support the greatest pressure, and, finally, be easier of computation than any other form known to the writer. The crest will be made one-tenth of the height, to agree with the crests of "standard types," approximately. The up-stream

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* *Transactions*, Am. Soc. C. E., Vol. xxxiv.

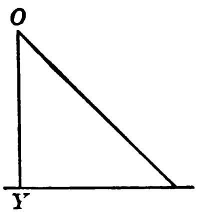
face will be vertical, though no more intricate mathematics is involved by giving it a batter. The line of the arch vertices will be vertical, though a batter to this and the up-stream face would result in additional economy of material. The profile of the buttress faces will be 1 to 1, or 45°. The width of the buttresses at the face will be battered uniformly from the crest, the amount of batter being a matter of computation.

Deduction of Formulas.

Let w = length of one section of the dam, from center to center of buttresses;

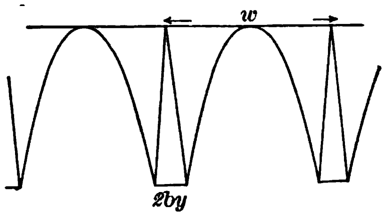
Let y = depth from crest, or height of dam;

Let b = buttress batter, so that $2by$ = width of buttress. Consider the buttresses first (see Figs. 1 and 2).



SECTION THROUGH BUTTRESS.

Fig. 1.



PLAN OF BUTTRESSES.

Fig. 2.

Area of Horizontal Section.

$$A = wy - \frac{2}{3}y(w - 2by) = \frac{1}{3}wy + \frac{4}{3}by^2 = \frac{y}{3}(w + 4by) \ldots (1)$$

Volume from Crest.

$$V = \int_0^y A\,dy = \frac{w}{3}\int y\,dy + \frac{4}{3}b\int y^2\,dy = \frac{y^2}{18}(3w + 8by) \ldots\ldots (2)$$

Center of Gravity of Horizontal Area from OY (see Fig. 1).

Take moments about OY. Let x = the distance of the center of gravity from OY.

$$xA = wy \times \frac{y}{2} - \frac{3}{5}y \times \frac{2}{3}y(w - 2by) = \frac{y^2}{10}(w + 8by)$$

$$x = \frac{3y}{10} \times \frac{w + 8by}{w + 4by} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Center of Gravity of Volume from OY.

$$\text{Distance } V = \int_0^y Ax\,dy = \int \frac{y}{3}(w + 4by)\frac{3}{10}y \times \frac{w + 8by}{w + 4by}\,dy$$

$$= \frac{w}{10}\int y^2\,dy + \frac{4b}{5}\int y^3\,dy = \frac{y^3}{30}(w + 6by)$$

$$\text{Distance} = \frac{3}{5y} \times \frac{w + 6by}{3w + 8by} \quad \ldots\ldots (4)$$

Now add a face to this pier or buttress, of uniform thickness, $\frac{y}{10}$. Its volume is $\frac{w y^2}{10}$. Its center of gravity is $\frac{y}{20}$ up stream from $O\ Y$.

Center of Gravity of Face and Buttress, Horizontally from O Y.

Take moments about $O\ Y$.

$$\text{Distance} = \frac{\frac{y^3}{30}(w + 6by) - \frac{w y^3}{200}}{\frac{y^2}{18}(3w + 8by) + \frac{w y^2}{10}} = \frac{3y}{160} \times \frac{17w + 120by}{3w + 5by} \quad \ldots (7)$$

This is down stream from the up-stream toe a distance

$$= \frac{11y}{160} \times \frac{9w + 40by}{3w + 5by} \quad \ldots\ldots (8)$$

The weight of masonry is its volume multiplied by its specific gravity. For purposes of comparison, the specific gravity assumed will be the same as that used by Edward Wegmann,* M. Am. Soc. C. E., *i. e.*, $2\frac{1}{3}$.

$$\text{Total weight} = W = \frac{28y^2}{135}(3w + 5by) \quad \ldots\ldots (9)$$

$$\text{Water pressure} = P = \frac{w y^2}{2} \quad \ldots\ldots (10)$$

(Both (9) and (10) are in terms of cubic feet of water.)

The Resultant of Forces.—When the reservoir is full, the resultant of forces is of the form $z = m\,v + c$, where z and v are the usual co-ordinates (except that z is positive downward), m is a tangent of direction and is equal to $\frac{W}{P}$, and c is a constant. (See Fig. 3.)

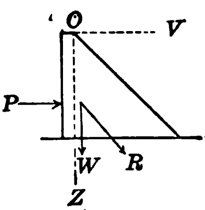


FIG. 3.

When $z = \frac{2}{3}y$, $v = \frac{3y(17w + 120by)}{160(3w + 5by)}$ [see Equation (7)],

$$\text{thus,} \quad c = \frac{y}{900w}(481w - 840by).$$

and the equation to the resultant becomes

$$z = \frac{56v}{135w}(3w + 5by) + \frac{y}{900w}(481w - 840by) \quad \ldots\ldots (11)$$

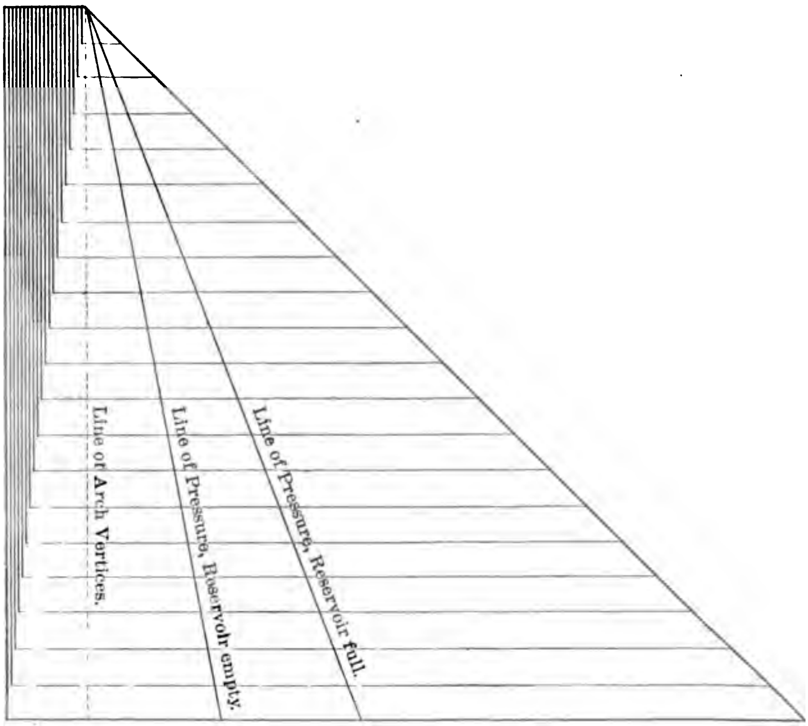
* "The Design and Construction of Dams, Including Masonry, Earth, Rock-fill, and Timber Structures, also the Principal Types of Movable Dams." Fourth edition, 1899.

This intersects the base, $z = y$, at

$$v = \frac{y\,(1257\,w + 2520\,b\,y)}{1120\,(3\,w + 5\,b\,y)} \qquad \text{(12)}$$

This is up stream from the down-stream toe a distance

$$= \frac{y\,(2103\,w + 3080\,b\,y)}{1120\,(3\,w + 5\,b\,y)} \qquad \text{(13)}$$



SECTIONS THROUGH BUTTRESSES OF DAMS FROM 10 TO 200 FT. IN HEIGHT, SHOWING LINES OF PRESSURE.

FIG. 4.

Intensity of Pressure.—With both dam and foundation rigid, the intensity of pressure at either toe is the average pressure multiplied by the fraction the numerator of which is four times the width of the base minus six times the distance of the center of pressure from the toe, and the denominator of which is the width of the base. In this case, it applies to the up-stream toe, but the factor $\frac{w}{2\,b\,y}$ must be

applied to the lower toe, because the pressure is borne on a length of toe $= 2\,b\,y$, instead of w. The average intensity of pressure is the weight divided by the base, or

$$I_{av.} = \frac{56\,y}{297\,w}\,(3\,w + 5\,b\,y) \ldots\ldots\ldots\ldots\ldots (14)$$

When the reservoir is empty, the intensity of pressure at the upper toe is

$$I_{max.} = \frac{7\,y}{3267\,w}\,(759\,w + 1412\,b\,y) \ldots\ldots\ldots\ldots (15)$$

When the reservoir is full, the intensity of pressure at the lower toe is

$$I_{max.} = \frac{1083\,w + 3080\,b\,y}{6534\,b} \ldots\ldots\ldots\ldots\ldots\ldots (16)$$

With these formulas, by substituting any desired value for the maximum intensity of pressure, the ratio $\frac{w}{b}$ can be obtained. w should be taken to make a good proportion with the height of the structure, then b can be calculated. These weights and pressures are all given in terms of cubic feet of water, so that the maximum intensities should be in the same units.

Sliding on the Base.—The angle of the resultant with the vertical is the angle of friction necessary to stability. Call this angle a. Then tan. a is the coefficient of friction necessary to prevent sliding on any horizontal base. Or, [see equations (9), (10) and (11)],

$$f = \tan.\ a = \frac{P}{W} = \frac{1}{m} \ldots\ldots\ldots\ldots\ldots\ldots (17)$$

Explanation of Table No. 1.

For reasons given below, $\frac{w}{b}$ will be taken as 1 000 in Table No. 1. Equation (2) gives the volume of a buttress. This, added to the face, $\frac{w\,y^2}{10}$, is the volume of the dam for a length w, so that the volume per foot of length will be

$$\frac{v}{w} = \frac{y^2}{18}\left(3 + 8\,y\,\frac{b}{w}\right) + \frac{y^2}{10} = \frac{y^2}{2\,250}\,(600 + y).$$

Column 2 of Table No. 1 gives this.

Equation (16) gives the intensity of pressure at the lower toe when the reservoir is full. When $\frac{w}{b}$ is 1 000, this becomes, in tons of 2 000 lbs., $\frac{135\,375 + 385\,y}{26\,136}$, given in Column 3.

The formula for maximum intensity of pressure when the reservoir is full (taken, so far, to agree with Wegmann's hypothesis), is

only the vertical component of that intensity. The actual pressure is the weight multiplied by sec. a (see Equation 17), and is borne on a base which is the base so far considered multiplied by cos. a. Thus, the intensity of pressure as above computed should be multiplied by the square of sec. a for the actual intensity of pressure. This is given in Column 4.

Equation (15) gives the intensity of pressure at the upper toe when the reservoir is empty. When $\frac{w}{b}$ is 1 000, this becomes, in tons of 2 000 lbs., $\frac{7\,y\,(189\,750 + 353\,y)}{26\,136\,000}$, which is given in Column 5.

The distance from the lower toe to the point on the base cut by the resultant of weight and pressure is given by Equation (13). When $\frac{w}{b}$ is 1 000, this becomes, in feet, $\frac{y\,(52\,575 + 77\,y)}{140\,(600 + y)}$, which is given in Column 6.

Similarly, the horizontal distance of the upper toe from the center of gravity is given by Equation (8). When $\frac{w}{b} = 1\,000$, this becomes, in feet, $\frac{11\,y\,(225 + y)}{20\,(600 + y)}$, which is given in Column 7.

TABLE No. 1.

y, in feet.	Volume per foot, in cubic feet.	Maximum Pressure, in Tons per Square Foot.			Distance from Toe to Center of Pressure.		Coefficient of friction, tan. a.	Factor against over-turning.
		Full.	Multiplied by sec.² a.	Empty.	Full.	Empty.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
10	27.1	5.32	8.64	0.52	6.24	2.12	0.7904	3.34
20	110.2	5.47	8.78	1.05	12.47	4.35	0.7776	3.34
30	252.0	5.62	8.91	1.61	18.67	6.68	0.7653	3.35
40	455.1	5.76	9.03	2.18	24.85	9.11	0.7534	3.35
50	722.2	5.91	9.16	2.77	31.00	11.64	0.7418	3.35
60	1 056.0	6.06	9.30	3.38	37.14	14.25	0.7305	3.36
70	1 459.1	6.20	9.44	4.02	43.26	16.95	0.7196	3.36
80	1 934.2	6.35	9.57	4.66	49.35	19.73	0.7090	3.36
90	2 484.0	6.50	9.69	5.33	55.44	22.60	0.6987	3.37
100	3 111.1	6.65	9.80	6.02	61.51	25.53	0.6888	3.37
110	3 818.2	6.79	9.92	6.72	67.55	28.55	0.6791	3.37
120	4 608.0	6.94	10.04	7.45	73.59	31.62	0.6696	3.38
130	5 483.1	7.09	10.18	8.19	79.61	34.77	0.6605	3.38
140	6 446.2	7.23	10.30	8.96	85.62	37.98	0.6515	3.38
150	7 500.0	7.38	10.43	9.73	91.61	41.25	0.6428	3.39
160	8 647.1	7.53	10.56	10.53	97.59	44.58	0.6344	3.39
170	9 890.2	7.68	10.69	11.35	103.55	47.96	0.6262	3.39
180	11 232.0	7.82	10.81	12.19	109.51	51.40	0.6181	3.40
190	12 675.1	7.97	10.93	13.02	115.46	54.90	0.6103	3.40
200	14 222.2	8.12	11.07	13.92	121.39	58.44	0.6027	3.40

Column 8 gives the coefficient of friction necessary to stability. See Equation (17).

The factor of safety against overturning is $\frac{W \text{ by its arm}}{P \text{ by its arm}}$, which, with these assumptions, becomes $3.3367 + 0.0034\,y$, being always more than 3.33, and increasing slightly with the height of the dam. This is given in Column 9.

By permission of Mr. Edward Wegmann, some of his figures will be given for comparison. Where possible, his hypotheses have been adopted with this in view. $\frac{w}{b}$ has been taken as 1 000 to agree with his maximum intensity of pressure for a 200-ft. dam.

TABLE No. 2.

50-Foot Dam.	Wegmann's No. 1.	Proposed Dam.
Height	50 ft.	50 ft
Crest	5 "	5 "
Specific gravity of masonry	2.33	2.33
Volume per foot of length	880.7 cu. ft.	722.2 cu. ft.
Maximum pressure, reservoir full	3.58 tons.	5.91 tons.
" " " empty	3.67 "	2.77 "
Coefficient of friction necessary	0.64	0.74
Coefficient against overturning	2.00	3.35

100-Foot Dam.	Wegmann's No. 2.	Proposed Dam.
Height	100 ft.	100 ft.
Crest	10 "	10 "
Specific gravity of masonry	2.33	2.33
Volume per foot of length	3322.7 cu. ft.	3111.1 cu. ft.
Maximum pressure, reservoir full	7.16 tons.	6.65 tons.
" " " empty	7.33 "	6.02 "
Coefficient of friction necessary	0.64	0.69
Coefficient against overturning	2.00	3.38

200-Foot Dam.	Wegmann's No. 3.	Proposed Dam.
Height	200 ft.	200 ft.
Crest	18.74 ft.	20 "
Specific gravity of masonry	2.33	2.33
Volume per foot of length	15195.1 cu. ft.	14222.2 cu. ft.
Maximum pressure, reservoir full	8.13 tons.	8.12 tons.
" " " empty	10.33 "	13.92 "
Coefficient of friction necessary	0.56	0.60
Coefficient against overturning	3.20	3.40

This comparison is not made in order to criticize Mr. Wegmann more than other analysts, but because his figures are reached after a digest of those of most previous writers, and show points of betterment over them. As before stated, the criticism is aimed at the assumption that, because a uniform construction to a safe profile insures a safe structure, uniformity is either necessary or economical.

The quantity of masonry in this proposed type is always less than in uniform-profile types.

The maximum intensity of pressure when the reservoir is full is more for low dams, less for high dams, but never reaches the high pressures of Mr. Wegmann's No. 3.

The maximum intensity of pressure when the reservoir is empty, up to 150 ft. in height, is less. Above that height, it is more. The vertical line from the center of gravity falls always above the middle third. The writer has never been able to see the reason for requiring it to fall inside the middle third. It does not fall dangerously near the upper toe. A foundation so yielding, or a construction so flimsy, that a wall, braced on one side with substantial buttresses, which would fail when not subjected to side pressure, is hardly to be considered in the catalogue of dam possibilities.

The factor of safety against overturning is greater in the proposed type.

Vol. XXVIII. APRIL, 1902. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

IMPROVEMENT OF THE BLACK WARRIOR, WARRIOR AND TOMBIGBEE RIVERS, IN ALABAMA.

By R. C. McCalla, M. Am. Soc. C. E.

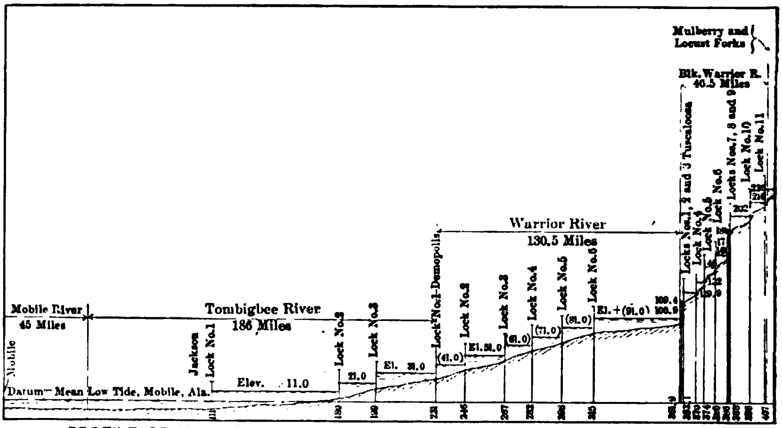
To be Presented September 3d, 1902.

General Characteristics.

The Black Warrior, Warrior, and Tombigbee Rivers, together with the Mobile River, form a chain of rivers flowing through the center of the great Warrior Coal Basin, and entering the Gulf of Mexico through Mobile Bay. The Black Warrior River is formed by the junction of the Mulberry and Locust Forks. At Tuscaloosa the name changes to Warrior. The Warrior flows into the Tombigbee about one mile above Demopolis, and the Tombigbee and Alabama Rivers join and form the Mobile River about 45 miles above the City of Mobile. Fig. 1 is a profile of these rivers, with the elevations of the locks. Fig. 2, a map of Alabama, shows the location of the rivers. The total length of these streams from the junction of Mulberry and Locust Forks to Mobile is 408 miles, and the total fall at low water is 214.5 ft., as shown in Table No. 1.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers with discussion in full will be published in *Transactions*.

Above Tuscaloosa the Black Warrior flows through a narrow gorge enclosed by steep hills and perpendicular rock bluffs. At low water there is a succession of level pools connected at frequent intervals by steep, shallow, rock rapids varying in fall from a few inches to 19 ft. The bed of the stream is generally of hard sandstone. Below Tuscaloosa these streams flow through alluvial valleys several miles wide, and are subject to overflow during floods. The bed is generally composed of thick layers of sand and gravel underlaid with clay or soft lime-stone. Occasional ledges of the latter rise nearly to the low-water surface, and form reefs across the river, but most of the shoals have beds of sand and gravel, and there is rarely more than 1 ft. fall through one shoal.



PROFILE OF MOBILE, TOMBIGBEE, WARRIOR AND BLACK WARRIOR RIVERS.

FIG. 1.

The minimum discharge of the Black Warrior and Warrior Rivers is about 150 cu. ft. per second, and the maximum discharge about 150 000 cu. ft. per second. The minimum discharge of the Tombigbee River below Demopolis is about 400 cu. ft. per second, and the maximum discharge probably approaches 300 000 cu. ft. per second. Large floods usually occur during the winter and spring, and at rare intervals during the summer and fall. They carry vast quantities of drift wood, and sometimes cause considerable loss of property. Smaller rises, which interfere with construction, but do no other damage, usually occur several times during each low-water season, from June to December. The most rapid rate of rise ever recorded at Tusca-

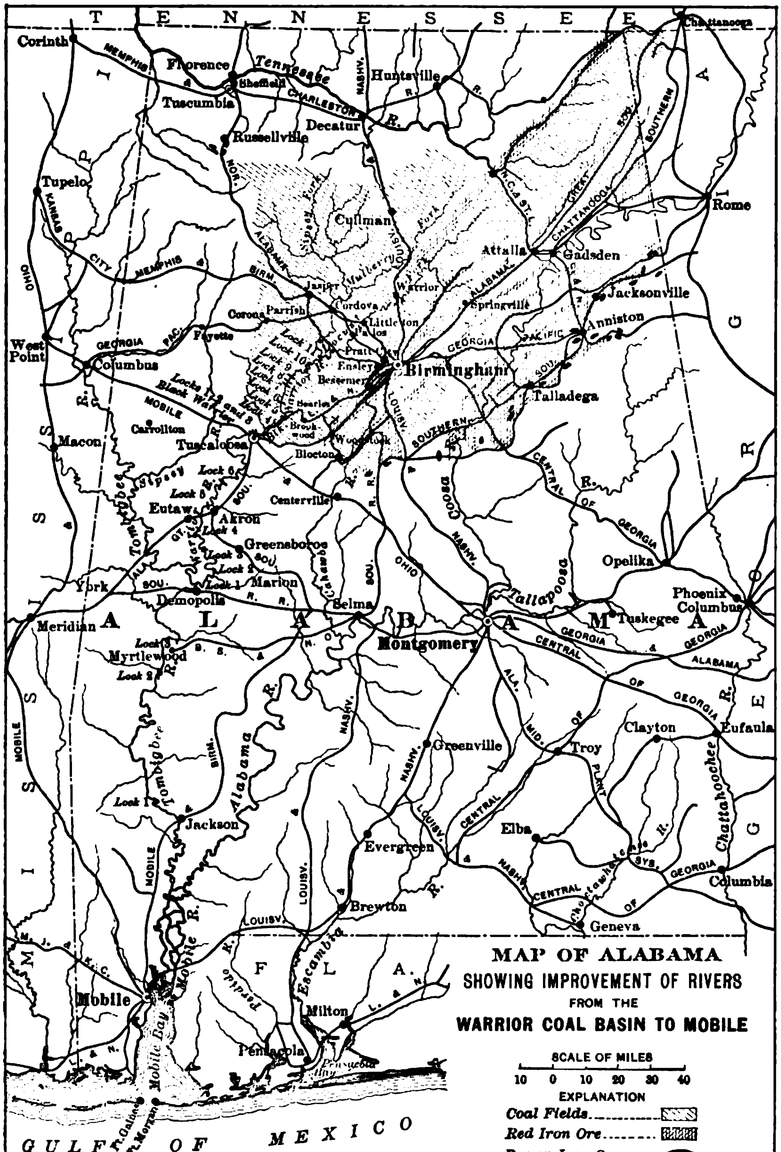

MAP OF ALABAMA
SHOWING IMPROVEMENT OF RIVERS
FROM THE
WARRIOR COAL BASIN TO MOBILE
SCALE OF MILES
10 0 10 20 30 40
EXPLANATION
Coal Fields
Red Iron Ore
Brown Iron Ore
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLA.
GULF OF MEXICO
Corinth
Florence
Sheffield
Tuscumbia
Huntsville
Decatur
Russellville
Chattanooga
Rome
Tupelo
Cullman
Attalla
Gadsden
Jasper
Cordova
Warrior
Springville
Jacksonville
Anniston
Parrish
Corona
Littleton
Fayette
West Point
Columbus
Birmingham
Pratt City
Ensley
Bessemer
Talladega
Carrollton
Macon
Tuscaloosa
Woodstock
Blocton
Centerville
Eutaw
Akron
Greensboro
Marion
York
Demopolis
Selma
Opelika
Phoenix
Columbus
Tuskegee
Meridian
Myrtlewood
Montgomery
Clayton
Eufaula
Greenville
Troy
Jackson
Evergreen
Elba
Columbia
Brewton
Geneva
Mobile
Milton
Pensacola
Ft. Gaines
Ft. Morgan
Tennessee
Tombigbee
Alabama R.
Coosa
Tallapoosa
Chattahoochee
Escambia
Mobile Bay

FIG. 2

loosa was 5 ft. per hour for 4 hours, after which the rate gradually decreased; but rises of 2 ft. per hour are not uncommon. The rate of rise is usually greatest at Tuscaloosa, and gradually decreases below that point. The maximum oscillation of the Black Warrior River varies from 15 to 50 ft. at different points. The maximum oscillation of the Warrior and Tombigbee Rivers is 67 ft. at Tuscaloosa; 47 ft. at Gray's Landing, 42 miles below Tuscaloosa; and 70 ft. at Demopolis, below which place it gradually decreases.

TABLE No. 1.

Description.	Length, in miles.	Fall, in feet.	Average low-water slope, in feet per mile.
Black Warrior River, Forks to Tuscaloosa.....	46.5	128.5	2.76
Warrior River, Tuscaloosa to Mouth of Warrior	130.5	58.5	0.45
Tombigbee River, Mouth of Warrior to Mouth of Tombigbee	186.0	27.5	0.15
Mobile River, Mouth of Tombigbee to City of Mobile.......	45.0	0.0	0.00
Totals and average.......	408.0	214.5	0.53

Previous to Improvement.

The Mobile River is tidal, and has ample depth for river navigation without improvement. Previous to improvement the Tombigbee River was navigable for light-draft steamboats to Demopolis about 9 months per annum, and the Warrior River to Tuscaloosa about 4 months per annum. Tuscaloosa was considered the head of navigation. Rafts and flatboats were brought down the Black Warrior on floods, but there was no other navigation on this stream.

Early Improvement.

Prior to the beginning of work on the present project, in 1888, no work was done on the Black Warrior, and work on the Tombigbee and Warrior Rivers was confined to removing snags, cutting overhanging trees, dredging through shoals, and building light dikes and training-walls to confine the water to the channel. This work was of considerable benefit to navigation, but did not extend the boating season materially, or do away with the uncertainty of navigation during a part of each boating season.

Present Project.

The present project is to obtain a waterway for the transportation of coal, in barges of 6 ft. draft, from the Warrior coal fields to the Gulf of Mexico, by a slack-water system of locks and dams. There will be twenty locks and dams, with a total lift of 230 ft., the upper lock and dam raising the low-water surface about 15.5 ft. at the junction of Mulberry and Locust Forks. The total cost will approximate $5 000 000. Beginning at the lower end, there will be: In the Tombigbee System, Lock No. 1 of 11 ft. lift and Locks Nos. 2 and 3, each of 10 ft. lift; in the Warrior System there will be Locks Nos. 1 to 6, each of 10 ft. lift; in the Black Warrior System there will be Lock No. 1 of 10 ft. lift, Lock No. 2 of 8½ ft. lift, Lock No. 3 of 10½ ft. lift, Lock No. 4 of 12 ft. lift, and Locks Nos. 5 to 11, each of 14 ft. lift. The elevations of these locks are shown on the profile, Fig. 1.

The locks are to have 52 ft. clear width, 286 ft. available length, 322 ft. length between hollow-quoins, and minimum depths of 6½ ft. on the miter sills and 7 ft. in the lock chambers. Steel lock gates and fixed dams about on line with the upper gates are to be used throughout. The work is now in progress, and is being carried out by the United States Government under the continuing contract system of river and harbor appropriations.

Work Accomplished—Tombigbee System.

Lock No. 1 is located and partly built at McGrew's Shoal, 111 miles above Mobile, on a reef of soft limestone which extends across the river a few feet below low water. Work on this lock was begun in 1896, and suspended for lack of funds in 1899. The work was done with hired labor, and was greatly retarded at various times by leaks in the coffer-dam, freshets and lack of funds. The lock walls are finished, but the gates and valves are not completed, and no work has been done on the dam or abutment. The lock walls are of concrete, composed of 1 part loose cement, 2½ parts sand, and 6 parts pebbles. They are founded directly on the soft limestone, trenches in which were dug about 2 ft. deep under each wall and filled with concrete for a footing course. Lagerdorfer Portland cement was used throughout. The dam and abutment will also, probably, be built of concrete.

The river below Lock No. 1 is tidal, and needs no improvement except dredging in places. Locks Nos. 2 and 3, between Lock No. 1

and Demopolis, have not yet been located, and no appropriation has been made for their construction.

Work Accomplished—Warrior System.

The surveys, borings and descriptions of lands needed for Locks Nos. 1, 2 and 3, have been completed, but no appropriation has yet been made for their construction. The general features of their design will follow closely those for Locks Nos. 4, 5 and 6 of the same system. The locks and abutments will be of Portland cement concrete on pile foundations. The dams will be timber cribs on pile foundations, similar to those at Locks Nos. 4, 5 and 6, of the Warrior System. Lock No. 1 is located in the Tombigbee River, just above Demopolis and just below the mouth of the Warrior, 230.6 miles above Mobile. Locks Nos. 2 and 3 are located in the Warrior River, 246.1 and 266.7 miles, respectively, above Mobile.

Locks Nos. 4, 5 and 6 are 282.2, 298.1 and 315.0 miles, respectively, above Mobile. These three locks are being built by contract, and are about half completed. They will probably be finished during 1902. The locks and abutments are being built on pile foundations, and will be of Portland cement concrete, 1 part cement, as packed in barrels, 3 parts sand, and 6 parts clean pebbles. The sand and pebbles are dredged from the river bed near the lock sites. The dams will be timber cribs with timber aprons, all founded on piles cut off about 1 ft. below low water.

Considerable dredging will be required to secure proper slack-water channel depths in the upper portions of all the pools of the Tombigbee and Warrior Systems.

Work Accomplished—Black Warrior System.

The change of name of the river, from Black Warrior to Warrior, occurs at the Tuscaloosa wagon bridge, 361.5 miles above Mobile. Locks Nos. 1, 2 and 3 are 361.9, 362.3 and 363.1 miles, respectively, above Mobile, overcoming the Tuscaloosa Falls, a series of rock rapids having a total fall of 24.5 ft. in about 2 miles. The Tuscaloosa wagon bridge is built on the lowest reef of these rapids, and here extensive channel work, largely rock excavation, partly in the Warrior and partly in the Black Warrior, was carried out in order to secure the required

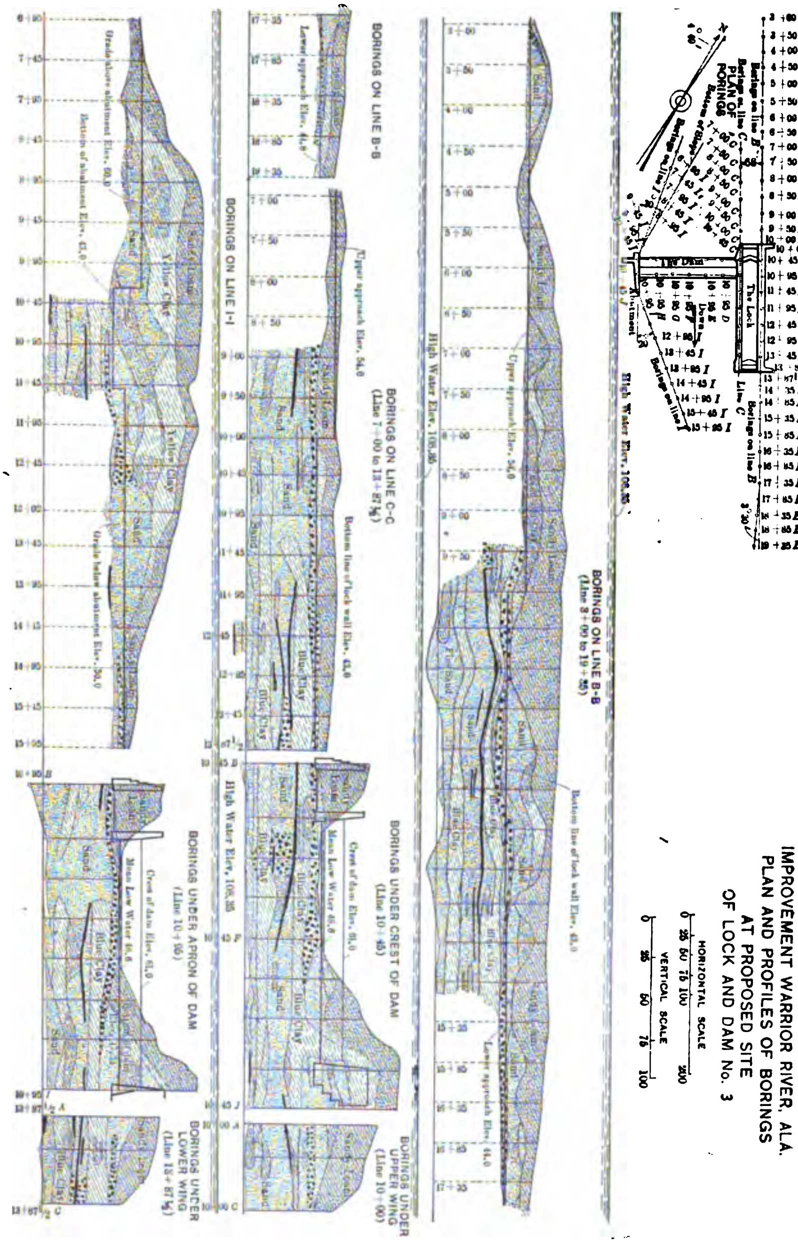

IMPROVEMENT WARRIOR RIVER, ALA.
PLAN AND PROFILES OF BORINGS
AT PROPOSED SITE
OF LOCK AND DAM No. 3
HORIZONTAL SCALE
VERTICAL SCALE
PLAN OF BORINGS
The Dam
The Lock
BORINGS ON LINE B-B (Line 3+00 to 19+35)
BORINGS ON LINE C-C (Line 7+00 to 13+87½)
BORINGS UNDER CREST OF DAM (Line 10+45)
BORINGS UNDER UPPER WING (Line 10+00)
BORINGS ON LINE B-B
BORINGS ON LINE I-I
BORINGS UNDER APRON OF DAM (Line 10+95)
BORINGS UNDER LOWER WING (Line 13+87½)
High Water Elev. 105.35

FIG. 8.

depth below pool level in the lower approach to Lock No. 1, which is built on the next reef above. Considerable rock excavation was also required in the lower approach to Lock No. 3.

All three locks and dams were built with hired labor. They were begun in 1888, and completed and opened for traffic in 1895.

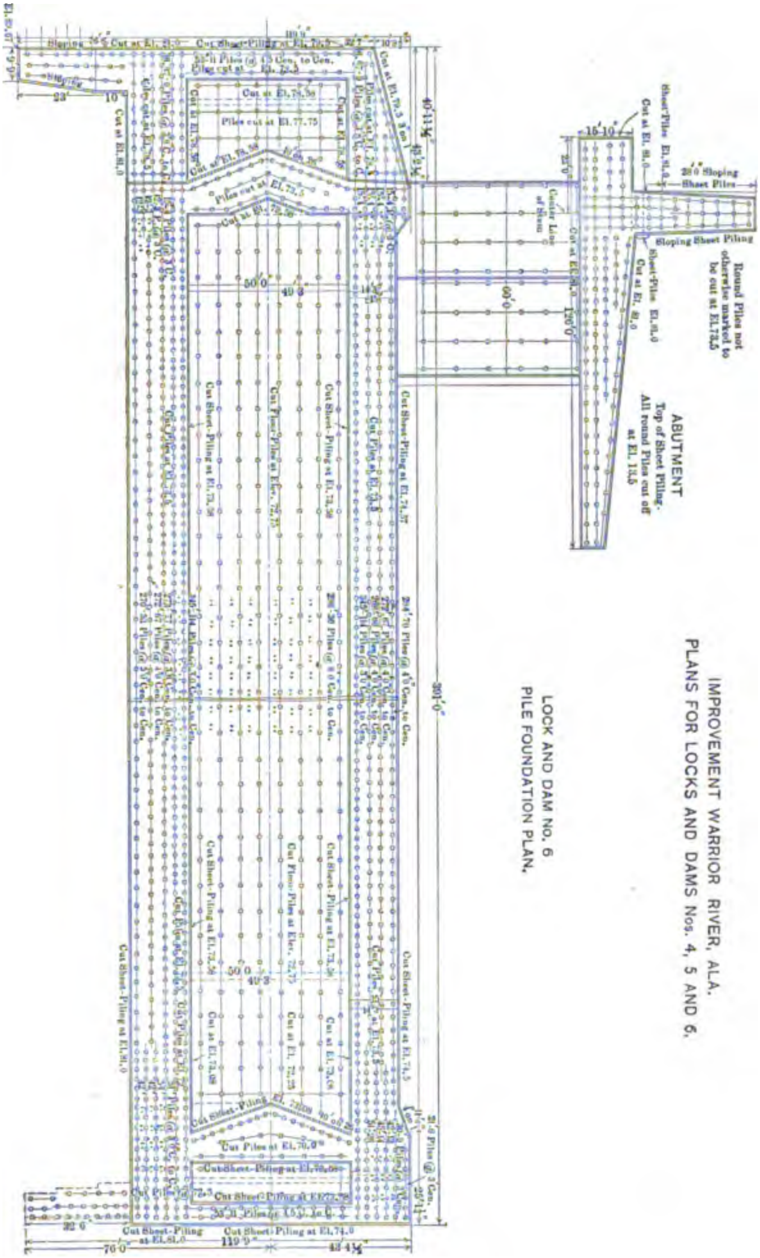
Lock No. 4 is 370.1 miles above Mobile, and is being built by contract. It is about half completed, and should be finished during 1902, Locks Nos. 5 to 11, inclusive, between Lock No. 4 and the junction of Mulberry and Locust Forks, have not yet been located, and no appropriation has been made for their construction.

ENGINEERING FEATURES—WARRIOR SYSTEM.

Location.—Trial borings were made at every practicable site for each lock, within limits of several miles, as fixed by the profile of the river, and, at the site finally selected, borings were taken 50 ft. apart under all structures and through the approaches. Borings were made by the water-jet method, 1-in. water pipe and 2-in. casing being used. The borings usually penetrated not less than 30 ft. below the lock floor. For Locks Nos. 1, 2 and 3, 322 borings were made, aggregating 13 716 ft. in depth, at a cost of $3 861, or about 28 cents per linear foot. The results of the borings were shown on drawings and exhibited to bidders (see Fig. 3). The site of Lock No. 5, looking up stream, is shown on Plate XVIII, Fig. 1; Lock No. 6, with the forms for the concrete walls, is shown on Plate XVIII, Fig. 2.

At first, efforts were directed toward finding suitable rock reefs on which to build, but it was soon discovered from the borings that such reefs did not exist, the rock found being in fragments or in thin ledges, and generally quite soft and unsafe for foundations. Efforts were then made to find locations where pile foundations could be driven with the minimum difficulty, rock being avoided. Limits for the location of each lock were fixed so that the lower miter sill with a given elevation would be from 2½ to 5 ft. below mean low water. Locations were sought in wide, shallow places with good, high banks and in curved instead of straight reaches. The locks are always located on the convex shore, in order to secure better protection from drift during floods, and on straight approaches parallel to the axis of the lock re-entering the stream.

Fixed or Movable Dams.—After very careful consideration of the



IMPROVEMENT WARRIOR RIVER, ALA.
PLANS FOR LOCKS AND DAMS Nos. 4, 5 AND 6.

LOCK AND DAM No. 6
PILE FOUNDATION PLAN.

FIG. 4.

question of fixed or movable dams, the former were adopted, for several reasons. Owing to the long low-water period of about 8 months annually, and the frequent occurrence during the other 4 months of stages which would drown the fixed dams, movable dams would add only about 3 months annually to the period of open-river navigation. Owing to the small size of the stream, tows will always be small, and probably will not require more than one or two lockages in passing a lock. Therefore, delays from lockages will be less than on large streams where large tows are difficult to maneuver and require more lockages to pass a lock. The low-water flow of the river, at times for several months, is only 150 to 300 cu. ft. per second, and, therefore, the dams must be as tight as practicable in order to maintain the pool level at the crest of the dam. Most types of movable dams are not tight enough to keep the pools full under such conditions. The cost of construction, operation and maintenance is much greater with movable than with fixed dams; and, owing to the enormous quantities of heavy drift carried by floods, the cost of operating and maintaining movable dams on this river would probably be greater than usual. The stream when improved will serve more as a canal than as a river, and is treated accordingly.*

Lift, Guard, Etc.—The lift of each lock was fixed at 10 ft., the guard at 13 ft., and the minimum length of the dam at 300 ft. These dimensions are based largely on experience under similar conditions at Lock No. 1 of the Black Warrior System; and it is believed that they will afford practically uninterrupted navigation, the dams being drowned on a rising river by the time the lock walls are submerged. Higher lifts were not adopted because it was feared they might raise the flood heights and thereby damage lands and other property in the valley.

Mounds.—The average width of the river at low water is about 200 ft.; therefore the length of dam adopted throws the locks and abutments well back into the banks, and causes heavy excavation, both for these structures and for the lock approaches at each site. It was not considered advisable to waste this material in the river, and therefore what is not needed for back-filling is used for building large mounds,

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* Usually one of the chief advantages of movable dams is that they reduce the height and duration of floods. In this case floods overflow the entire valley to an average depth of 5 to 10 ft. for several miles in width. It is probable, therefore, that fixed dams of 10 ft. height and 300 ft. length in the low-water channel will have little, if any, influence on the height and duration of floods.

IMPROVEMENT WARRIOR RIVER, ALA.
PLANS FOR LOCKS AND DAMS Nos. 4, 5 AND 6.
LOCK No. 6.

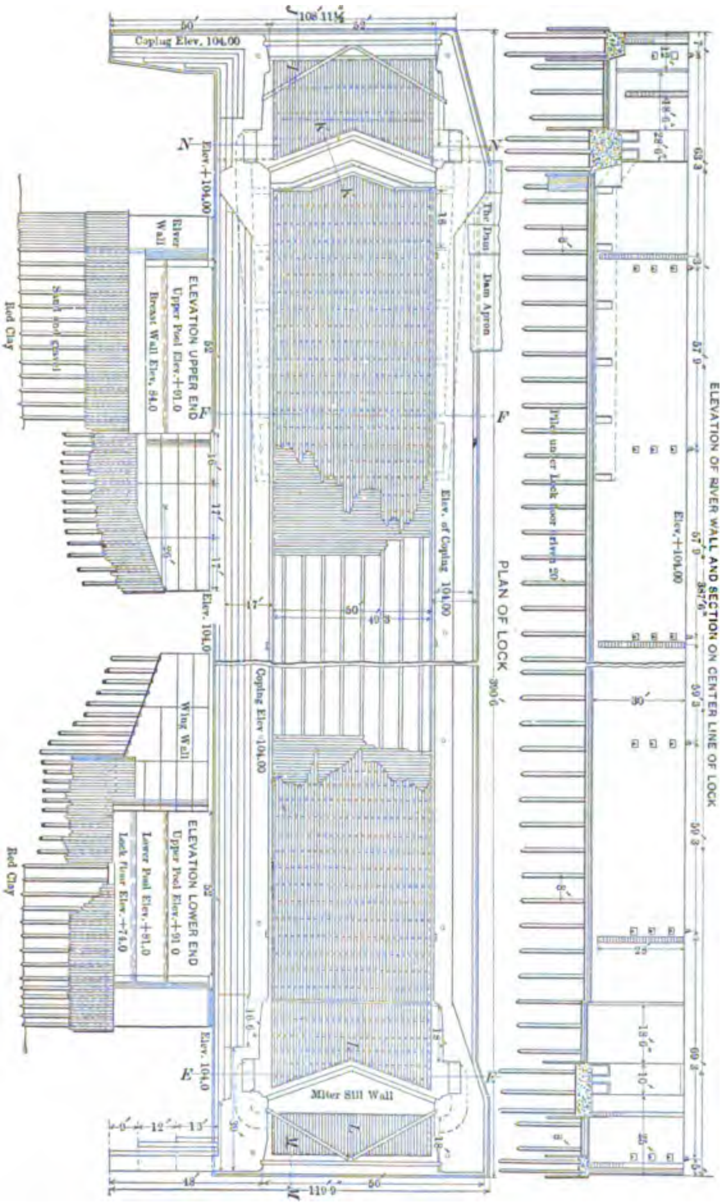


FIG. 5.

5 ft. above high water, in rear of the locks and abutments. These mounds will be quite useful as places for storing property, etc., as the entire reservations, except at one lock site, are subject to overflow. The lock houses will be built on the mound back of the lock.

Plans.—Detailed drawings of Lock and Dam No. 6 are shown in Figs. 4 to 17.

Concrete.—The concrete is mixed in a 4-ft. cubical mixer making eighteen revolutions in two minutes, and the usual charge is 1 bbl. of packed cement, 3 bbls. of sand, and 6 bbls. of pebbles, which make about 29 cu. ft. of concrete rammed in place. In all, 17 688 cu. yds. of concrete and mortar facing, containing 16 973 bbls. of cement, were placed during 1901, giving an average of 1.042 cu. yds. per barrel. The sand and pebbles are quite clean, the former being coarse and sharp, and the latter about ¼ in. to 1 in. in diameter, and both showing only 33 to 34% of voids. Mortar facing, 1¼ to 1½ ins. thick, composed of 1 part packed cement and 3 parts sand, is used on all exposed faces of the walls. The walls are built in blocks about 20 ft. long and of the full thickness of the walls. The blocks are separated by continuous vertical joints from bottom to top to provide for contraction, and the joints are indicated by V-shaped grooves in the faces of the walls. Alternate blocks are built first between bulkheads, two blocks being built usually at the same time. The intermediate blocks are built after the bulkheads are removed. The concrete is well rammed in layers about 6 ins. thick after ramming, and is usually wet enough to quake moderately when well rammed. Horizontal joints are left where the work stops at night, and are covered with ½ in. of mortar before fresh concrete is deposited next day. After the forms are taken down, rough places in the exterior finish are chiseled smooth, and, to improve the finish of the walls, several coats of a thin wash of 2 parts cement and 1 part sand are applied.

Stability of the Walls.—The lock walls are 30 ft. in height above the floor, and are built on footing courses 2 ft. wider than the bases of the walls. The faces next to the lock chamber are vertical. The bank wall is designed as a retaining wall, and its average thickness, not including the footing course, is about 37% of its height. The back is stepped so that a part of the back-filling adds to the stability of the wall against overturning. In designing the river wall it was assumed that 17 ft. is the maximum head that will come against it, this being

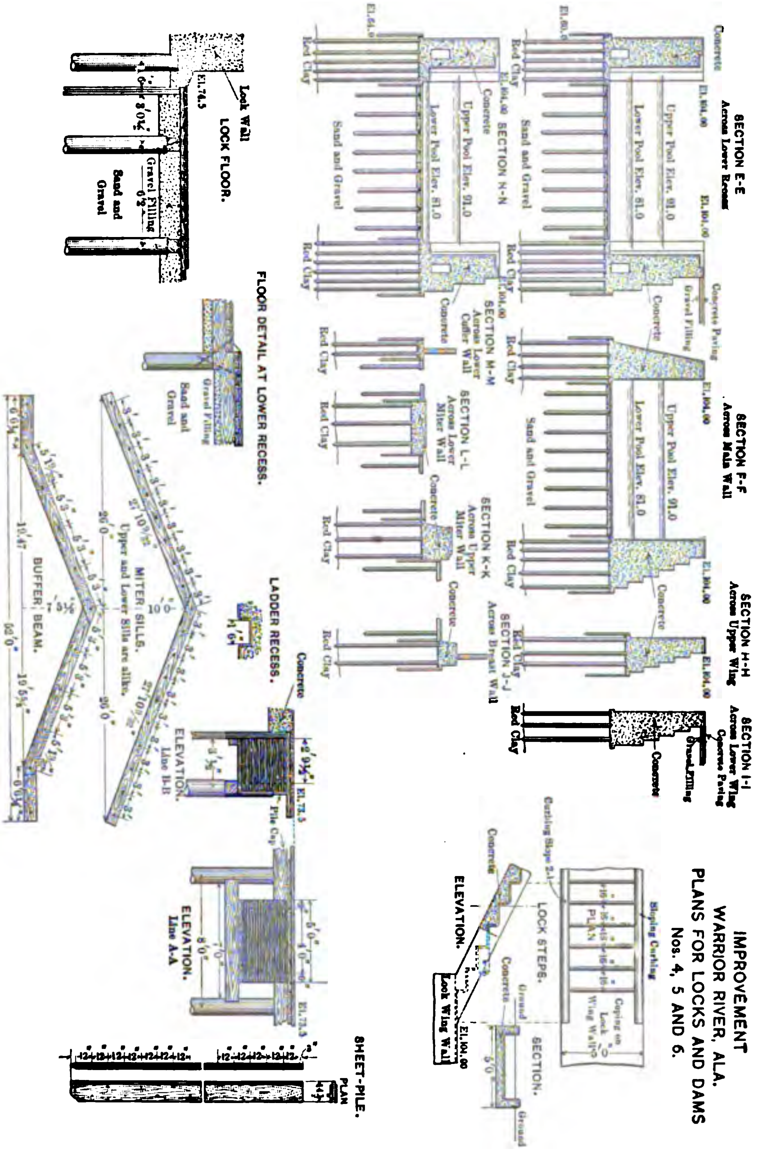

IMPROVEMENT
WARRIOR RIVER, ALA.
PLANS FOR LOCKS AND DAMS
Nos. 4, 5 AND 6.
SECTION E-E
SECTION F-F
Across Main Wall
SECTION H-H
Across Upper Wing
SECTION I-I
Across Lower Wing
SECTION N-N
SECTION M-M
SECTION L-L
SECTION K-K
SECTION J-J
Across Breast Wall
LOCK FLOOR.
FLOOR DETAIL AT LOWER RECESS.
LADDER RECESS.
MITER SILLS.
Upper and Lower Sills are alike.
BUFFER BEAM.
ELEVATION.
Line B-B
ELEVATION.
Line A-A
SHEET-PILE.
PLAN
LOCK STEPS.
ELEVATION.
SECTION.
Lock Wing Wall
Upper Pool Elev. 91.0
Lower Pool Elev. 81.0
Sand and Gravel
Red Clay
Concrete
Gravel Filling

Fig. 6.

with the lower pool 10 ft. above low water and the lock chamber pumped out. The intention is never to place the coffer timbers above this height, so that should the water rise higher it will pass over the coffer timbers and relieve the head by flooding the lock chamber. Under this head the river wall has a factor of safety of 6 against overturning. With a head of 24 ft. against the river wall the factor of safety is 1.8, and with a head of 30 ft. the river wall would overturn. None of the walls can slide, owing to the nature of the pile foundations.

The buttresses are located so that the line of thrust of the gates will pass diagonally through them, but they are made thicker than necessary to take up this thrust, in order to give room for the gate maneuvering gearing on top.

The abutment stem is a core-wall running back into the bank, with embankments on both sides. These embankments are held in place by the abutment wings, which have a face batter of 2 ins. per foot, and are designed as surcharged retaining walls. Their average thickness is about 40% of their height. The abutment also has a footing course 2 ft. wider than the bases of the walls. This is not included in computing the average thickness of the walls, and is supported by the dam and a minimum depth of 6½ ft. of water above the footing course in the lower pool.

Pile Foundations.—Both foundation piles and sheet-piles were forced into the sand and gravel under the sites with a combination of hammer and water-jet, practically to refusal, care being taken as the penetration decreased to lessen the blow so as not to injure the pile. While the hammer was of great assistance, the jet proved to be the main dependence in getting the piles down, and they could not have been driven without it.

Every wall is entirely surrounded by an inner and outer row of Wakefield sheet-piling. The object of this is both to confine the material under the walls so that it will assist the foundation piles in sustaining their load, and to reduce the percolation of water under the walls due to difference in head. The outer row of sheet-piling also serves as part of a coffer-dam during construction.

The round foundation piles are driven 3 to 4 ft. between centers in the space between the two walls of sheet-piling. They are cut off 6 to 12 ins. above the bottom of the concrete, which is rammed around

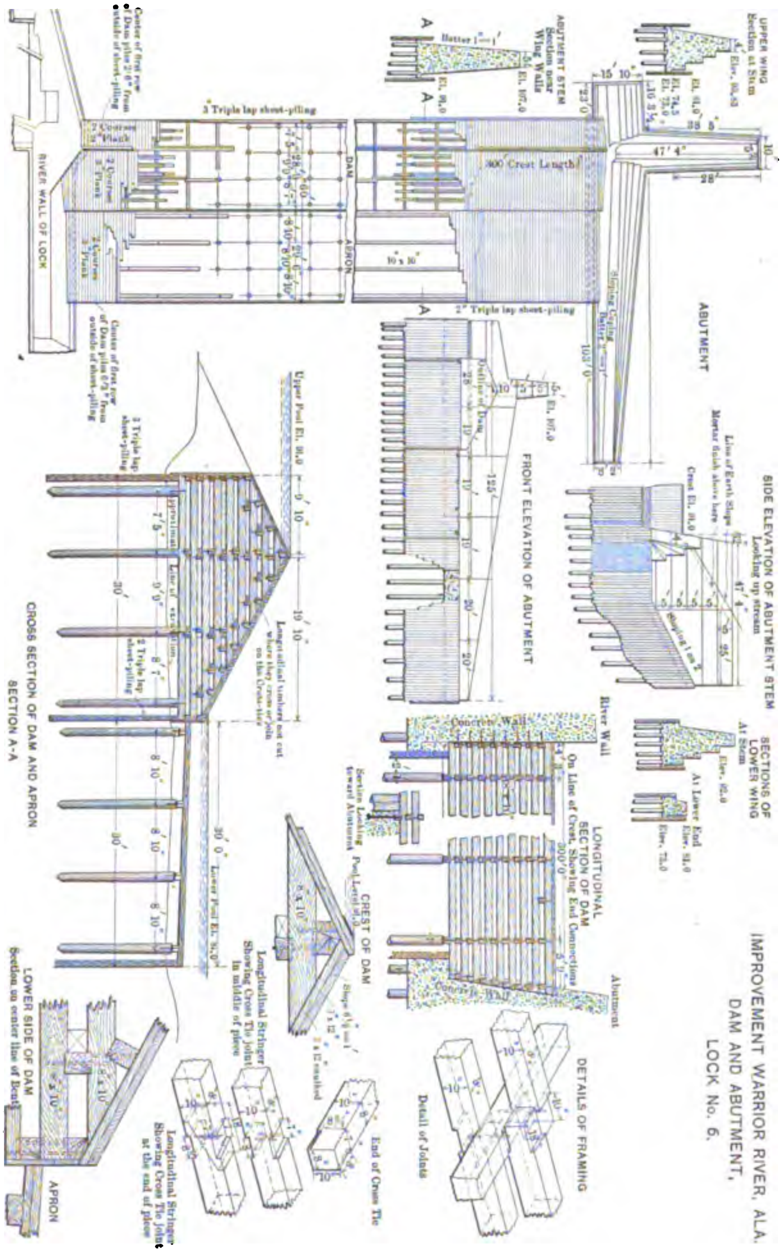


Fig. 7.

and over them. They are so close together that grillage was considered entirely unnecessary and probably detrimental to the work. The concrete, therefore, rests directly on the pile heads, from which the bark is removed. The maximum loading on the foundation piles is about 20 tons each.

The average penetration of the sheet-piles is about 12 ft., and of the round piles about 18 ft., below the bottom of the masonry. So far, not the slightest evidence of settlement has been detected. See Fig. 4.

Lock Floors.—As the floor might at times be subjected to an up-thrust, due to 17 ft. head, a tight concrete floor, safe against this up-thrust, would have to be very massive and costly. It was decided, therefore, to use a timber floor, tight against downward leakage, to avoid loss during lockages, and open for upward leakage, to avoid up-thrust. Floor piles are driven in parallel rows and capped longitudinally with 10 x 10-in. timbers. The foundation is then covered with 15 ins. of pebbles flush with the tops of the caps and intended to permit the water to circulate freely under the floor. The caps and pebbles are then covered with a cross-layer of 3-in. plank caulked with oakum, and this with a longitudinal layer of 2-in. plank, to keep the oakum in place and protect it from culvert scour. This floor is designed for a maximum downward pressure due to 10 ft. head without aid from the pebble filling between the caps. The maximum head occurs at low water with the lock chamber filled.

The floor is relieved from up-thrust by 2-in. auger holes spaced about 10 ft. apart. This design is based on the supposition that when the lock is pumped out for repairs water under the maximum head of 17 ft. will percolate slowly under the sheet-piling and through the mass of sand and gravel under the lock. On reaching the pebble filling it will circulate more freely, pass up through the auger holes, and flow to the drainage pumps. It is believed that water due to percolation will thus be kept in motion, and cannot exert dangerous up-thrust. Downward leakage through the auger holes when the lock chamber is filled is prevented by ball-valves. See Fig. 5. The details of the valve are shown in Fig. 8.

Drain Tile.—Single lines of 8-in. drain tile, on a grade of 6 ins. per 100 ft., and emptying into the lower pool below the pool level, are laid behind the lock bank wall and the lower wing of the abut-

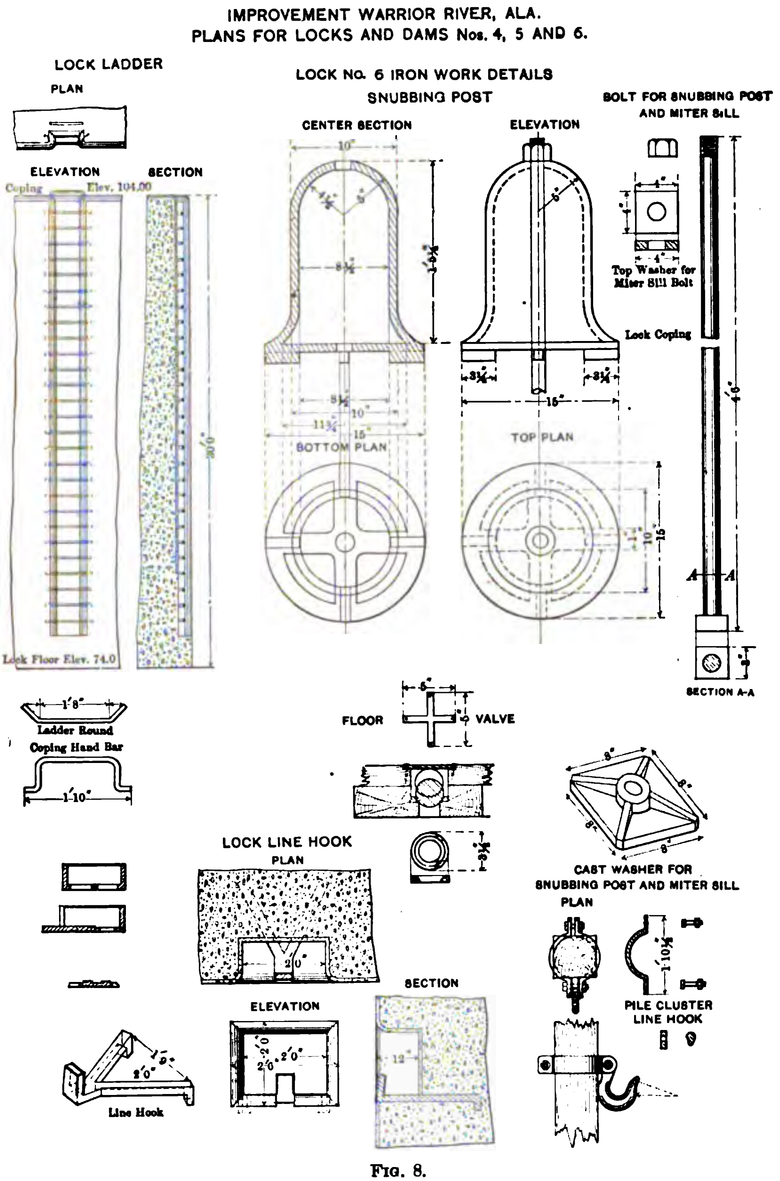

IMPROVEMENT WARRIOR RIVER, ALA.
PLANS FOR LOCKS AND DAMS Nos. 4, 5 AND 6.
LOCK LADDER
PLAN
ELEVATION
SECTION
Coping
Elev. 104.00
Lock Floor Elev. 74.0
30'0"
1'8"
Ladder Round
Coping Hand Bar
1'10"
Line Hook
LOCK NO. 6 IRON WORK DETAILS
SNUBBING POST
CENTER SECTION
ELEVATION
BOTTOM PLAN
TOP PLAN
BOLT FOR SNUBBING POST AND MITER SILL
Top Washer for Miter Sill Bolt
Lock Coping
SECTION A-A
FLOOR
VALVE
CAST WASHER FOR SNUBBING POST AND MITER SILL
PLAN
PILE CLUSTER LINE HOOK
LOCK LINE HOOK
PLAN
ELEVATION
SECTION

FIG. 8.

ment to drain the back-filling. Vitrified tiling is used, laid with open joints and surrounded with pebbles to serve as a screen. See Fig. 10.

Dams.—Concrete dams on pile foundations were first contemplated; but this plan was abandoned because it involved a necessity for coffer-dams, difficulty in disposing of the flow of the river during construction, and the possible danger of wash-outs underneath, which would be very difficult to repair.

The plan adopted is a bottomless timber crib, resting on piles and filled with "one man" stones, the interstices in which are filled with sand and gravel washed in to reduce voids and add to the weight, but no cement is used. The crib is sheathed with plank, which is caulked to reduce leakage, and the filling rests directly on the bed of the river. The base of the dam is 30 ft. wide, and has a row of Wakefield sheet-piling under each face, to reduce percolation under the dam and prevent the escape of the filling. The crest of the dam slopes both ways to an apex 10 ft. from the up-stream face. Below the dam and under the pool level is a timber apron, 6 ins. thick and 30 ft. wide, resting on piles, and terminating with a row of Wakefield sheet-piling under the down-stream edge, to hold the filling under the apron and guard against undermining below. Should scour take place below this apron, it is proposed to dump in big stones until erosion ceases.

It is believed that this dam can be built during low water without coffer-damming, one course being placed and filled at a time, the river running over in a sheet, and the work being protected locally with flash-boards. It is also believed that, should a wash-out start under the dam, the filling will drop into and choke the cavity while small. Then the sheathing can be removed and the filling replaced in the top of the dam, which can be examined at low water by sounding through augur holes, which can be bored and afterward plugged. See Fig. 7.

Gates.—The gates are built of soft steel of 54 000 to 64 000 lbs. ultimate strength per square inch, and designed for a fiber stress of 10 000 lbs. per square inch. They are of the mitering horizontal-girder type, with single skin, and largely follow the designs of the Deep Waterways Commission. The girders have straight down-stream flanges, in order to simplify construction, and curved up-

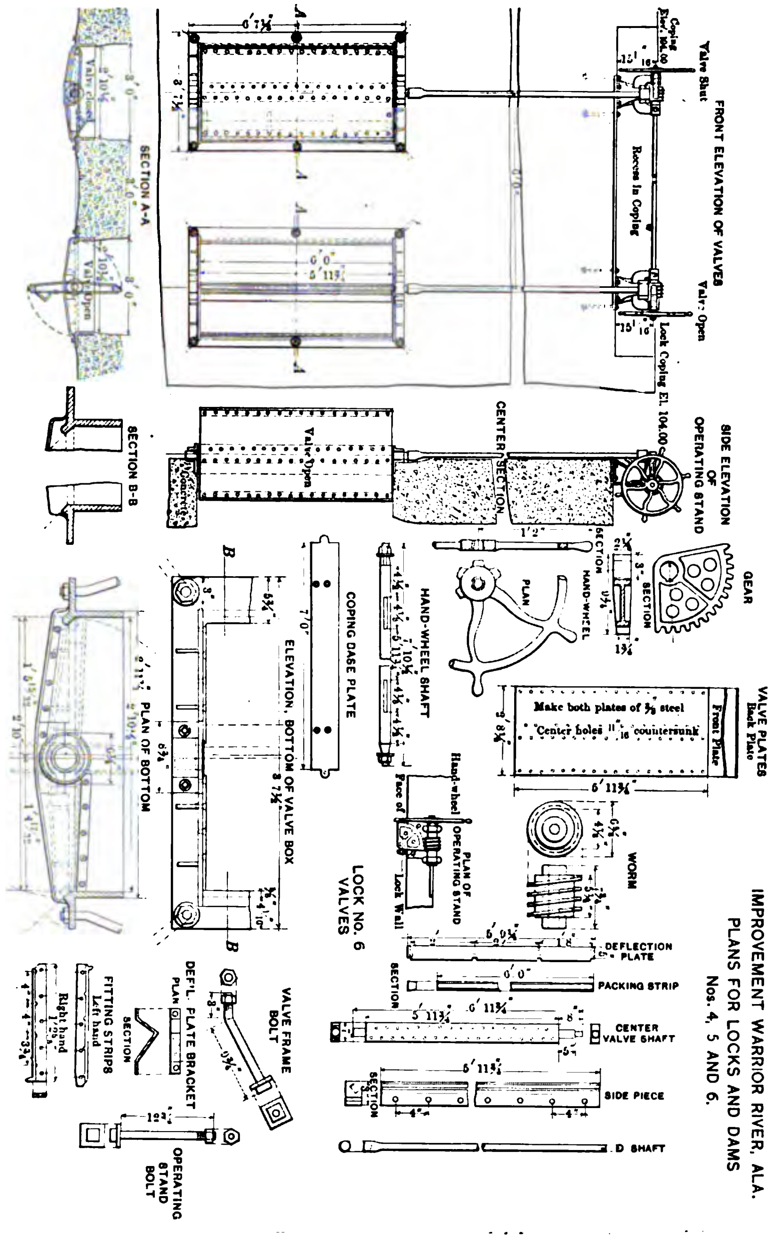

IMPROVEMENT WARRIOR RIVER, ALA.
PLANS FOR LOCKS AND DAMS
Nos. 4, 5 AND 6.
LOCK NO. 6
VALVES
FRONT ELEVATION OF VALVES
Valve Shut
Valve Open
Recess in Coping
Lock Coping El. 104.00
SIDE ELEVATION OF OPERATING STAND
CENTER SECTION
SECTION A-A
SECTION B-B
GEAR
SECTION HAND-WHEEL
PLAN
HAND-WHEEL SHAFT
COPING BASE PLATE
ELEVATION, BOTTOM OF VALVE BOX
PLAN OF BOTTOM
VALVE PLATES
Back Plate
Front Plate
WORM
PLAN OF OPERATING STAND
Lock Wall
DEFLECTION PLATE
PACKING STRIP
CENTER VALVE SHAFT
SIDE PIECE
D SHAFT
VALVE FRAME BOLT
DEF'L. PLATE BRACKET
FITTING STRIPS
Left hand
Right hand
OPERATING STAND BOLT

FIG. 9.

stream flanges, in order to distribute the metal to advantage. The bottom girder bears against the miter-sill cushion, which is also straight on the bearing surface. The skin plates are ⅜ in. thick, this being the minimum thickness of metal used in the gates owing to possible weakening from rust. The girders are fastened to the miter and heel posts with connecting angles. A wooden footway is bolted to the top of the gates.

The miter posts are of oak, backed with built-up steel channels to stiffen them. Wood is used for the miter-post cushions because they can be trimmed after the gates are erected, so as to properly adjust

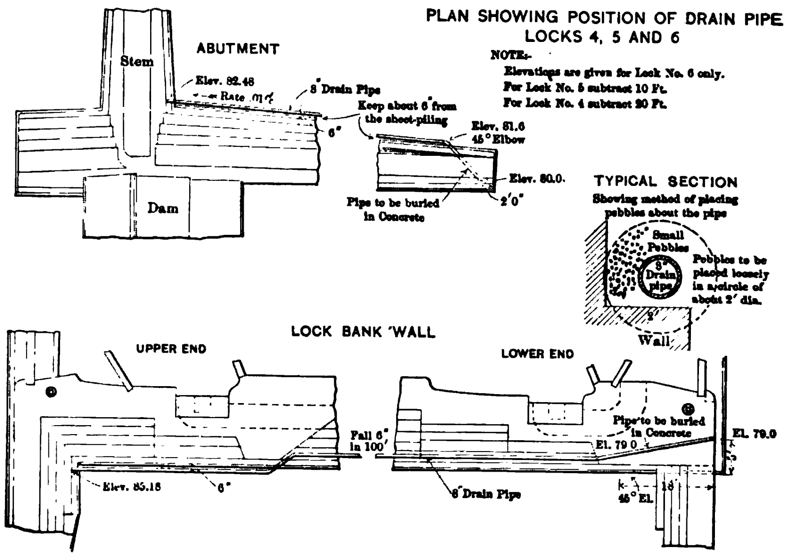


FIG. 10.

the length of the gates and at the same time secure a perfect fit between the two posts. Also, these cushions can be easily renewed. The heel posts, owing to the difficulty of renewing wooden ones, are made of cast iron, in sections about 10 ft. long, joined with internal flanges having male and female bolted connections. Vertical dovetailed grooves are cast along the bearing surfaces of the post, and are used to hold in place strips of lead packing, which are trimmed and adjusted to make a water-tight joint with the hollow quoin. In order to avoid the wear of this packing, the heel post is hung eccentrically

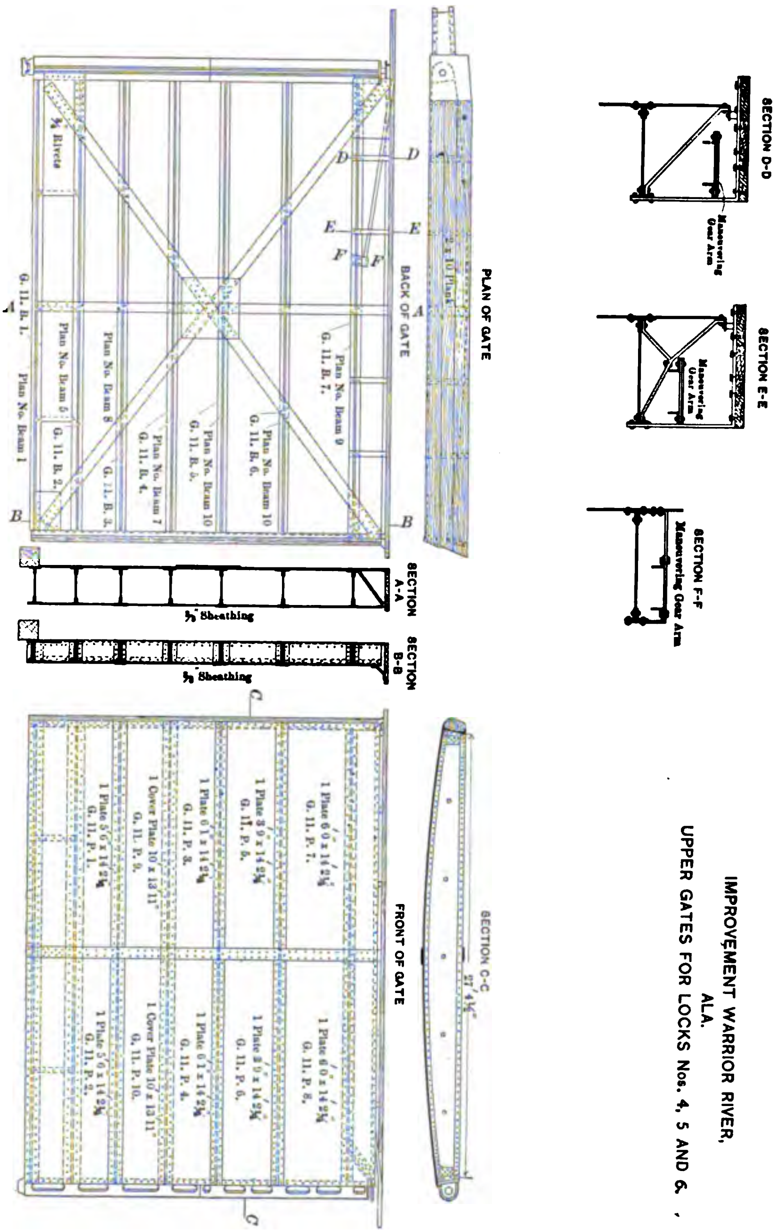


FIG. 11.

IMPROVEMENT WARRIOR RIVER, ALA.
UPPER GATES FOR LOCKS Nos. 4, 5 AND 6.

½ in., and plays off from the quoin when the gate begins to open. The quoins are cast iron, and planed true on the rubbing and bearing surfaces. The bottom of the heel post is fitted with a cast-iron socket which rests on a cast-iron pivot bolted to the masonry footing course. The bearing surfaces of the socket and pivot are chilled. The top gudgeon is a 4-in. steel pin supported by two steel plates, between which the gate yoke works. The yoke is attached to the anchorages with a gib and key which permit adjustment and also permit the removal of the yoke with ease. The yoke, etc., fits in a covered cast-iron box below the coping, where it is out of the way and yet is easily accessible for adjustment. The anchorages, which slope downward and are provided with anchor plates at the lower ends, are built into place with the concrete walls.

A stiff, built-up, operating lever is bolted to the top of the gate, and projects backward, swinging just above the coping. A small trolley travels in a slot at the outer end of the lever, and to this is attached an endless sprocket chain which passes around two idlers and a driving wheel. The latter is operated by a hand-lever and crab, the lock hand walking around the crab and pushing the lever in one direction to open the gate and reversing the motion to close it. This hand-lever is unshipped during floods, and the remainder of the gearing, being quite close to the coping and made as flat as practicable, offers little obstruction to floating drift. This maneuvering gear is quite simple and effective. It does not easily get out of order, is quite durable, and probably compares favorably with any other method of operating lock gates by hand. See Figs. 11 and 13.

Valves.—The valves are balanced gates with vertical axes, and are built of soft steel of 54 000 to 64 000 lbs. ultimate strength. There is a steel center shaft, 3 x 7 ins., with 2¾-in. journals and two side bars of cast iron holding rubber packing strips in dovetailed grooves. The center shaft has a bottom adjustable step-bearing to reduce friction. The center shaft and side pieces are covered with two steel plates, ⅜ in. thick, riveted through. The flat shaft is used to reduce the thickness of the valves, and the rivet heads are countersunk, the object being to have the open valve obstruct the flow into the culvert as little as practicable. The valve frame is a casting in one piece, built into the masonry and surrounding the valve. A steel rod, with a socket on its bottom end fitting over the square top of the valve shaft,

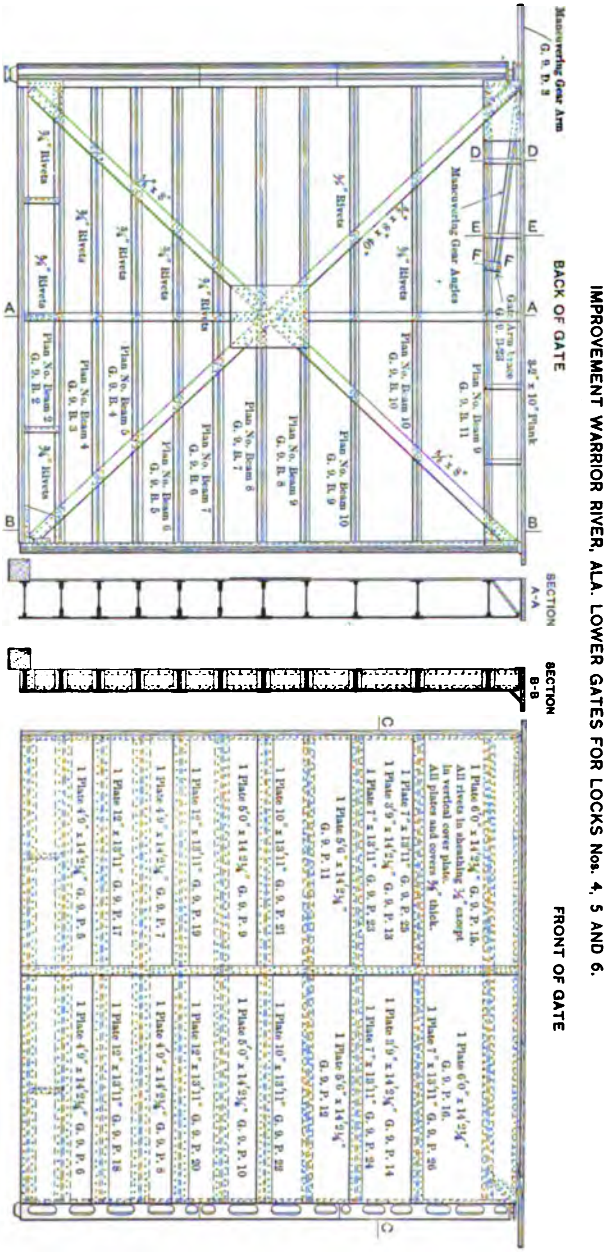

IMPROVEMENT WARRIOR RIVER, ALA. LOWER GATES FOR LOCKS Nos. 4, 5 AND 6.
BACK OF GATE
SECTION A-A
SECTION B-B
FRONT OF GATE

FIG. 12.

extends up the face of the wall to the maneuvering gear, which is placed in a recess 15 ins. below the coping in order to protect it from drift. To the top of this rod is keyed a sector worm-gear which meshes into a worm on a horizontal shaft parallel to the axis of the lock. The valves are operated in pairs from the worm shaft, which has, between the two worms, a flanged coupling which admits of adjustment so as to close the two valves exactly together. The worm shaft is operated by hand-wheels at either end, which are removed during floods, on account of drift. The remainder of the operating machinery is below or about level with the coping, and, therefore, is protected from drift.

The worm gear is used for operating the valves because it gives ample power under all conditions, and, while it acts quickly enough, it does not permit of very rapid movement of the valves, and thereby protects them from water hammer when it is necessary to close them against a head of water. Steel valves are also preferred to cast valves, because they stand shock from water hammer with much more safety than cast valves.

A steel deflection plate is fastened to the inside of the valve on the half that swings outward into the lock chamber. As soon as the valve begins to open, the reaction of the water against this plate helps to swing the valve. The plate is located so that it does not reduce the area of the waterway when the valve is fully opened. Owing to the proximity of the valves to the gates, it has been found important to have the up-stream half of the valve swing outward into the lock chamber. This gives the water a more direct flow into the culvert while the valve is swinging than if the down-stream half swung outward, and, therefore, the valve swings more easily and smoothly. The main objects sought in designing this valve were simplicity and durability, and it has proved to be quite satisfactory in practice (see Fig. 9).

Culverts.—The culverts pass through the lock walls, around the gates at each end of lock. This avoids valves in the gates, which would tend to weaken the gates and complicate their construction. It also results in much simpler and cheaper construction than putting the culverts under the lock floor. The upper culverts extend about one-third the length of the lock chamber, and have from each culvert six different outlets into the lock chamber at intervals of 18 ft., from center to center, in order to distribute the flow and avoid objection-

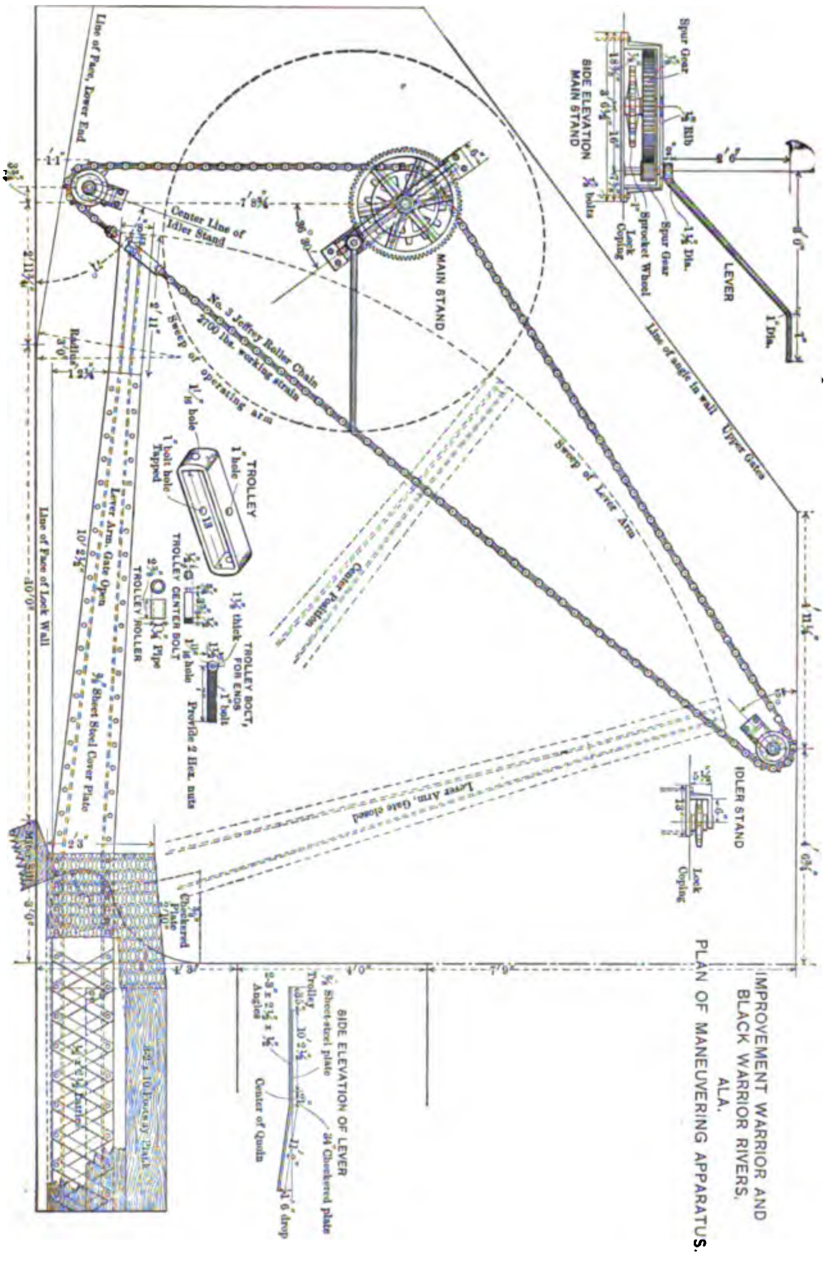

IMPROVEMENT WARRIOR AND BLACK WARRIOR RIVERS, ALA.
PLAN OF MANEUVERING APPARATUS.
MAIN STAND
LEVER
IDLER STAND
SIDE ELEVATION MAIN STAND
SIDE ELEVATION OF LEVER
TROLLEY
TROLLEY CENTER BOLT
TROLLEY ROLLER
TROLLEY BOLT, FOR ENDS
Line of Face, Lower End
Line of Face of Lock Wall
Center Line of Idler Stand
No. 3 Jeffrey Roller Chain
2700 lbs. working strain
Sweep of operating arm
Sweep of Lever Arm
Line of angle in wall
Upper Gates
Lever Arm, Gate Open
Lever Arm, Gate closed
Center Position

FIG. 13.

able agitation in the lock chamber. The lower culverts each have a single outlet directed so as to wash away flood deposits in the lower bay.

There are four valves at each end, giving, combined, a clear opening of 58.17 sq. ft. for filling or emptying. The two culverts at each end have a combined area of cross-section of 60 sq. ft. These dimensions, with 10 ft. lift, give an estimated time of 6.3 minutes, using c equal 0.6, for filling or emptying the lock chamber (see Figs. 14 and 15).

Coffer Timbers.—These are to be used when it is necessary to pump out for repairs, there being no guard gates provided. The timbers will be each 12 x 18 ins. x 56 ft., and will be lowered with a derrick-boat into the coffer grooves near the extreme ends of the walls, being thus built up into walls of timber 10 ft. above the lower pool and 6 ft. above the upper pool level. Triangular center posts, each having two steel channels placed so as to receive the ends of the brace timbers, will then be placed upright against the middle of the coffer timbers, and 12 x 6-in. braces will then be lowered into the center-post channels at one end and into the brace grooves at the other end. The lock chamber will then be ready for pumping out, sawdust, or cinders, or canvas being used for reducing leakage between the coffer timbers. Should the pools rise above the coffer timbers, the lock chamber will be flooded and the pressure against the river wall relieved (see Figs. 14 and 15).

Bank Protection.—The horizontal space between the bank-wall wings and the slope immediately back of these wings will be paved with concrete blocks, 6 ins. thick and about 3 ft. square, built in place on a bed of sand and gravel 6 ins. thick. The approach slopes to the lock and abutment, for the full length of the lower approaches and for 100 to 150 ft. above the dam, will be protected with hand-placed rip-rap, 12 ins. thick, of hard, durable stone. It is expected that this rip-rap will slip in spots while floods are receding, and will have to be repaired from time to time until it becomes covered with a thick growth of willows and other vegetation.

Pile Clusters.—Heart piles will be driven in clusters above and below the locks to guide vessels in entering. Each cluster will contain eight piles, seven cut off level with the coping of the lock, and a center pile projecting 18 ins. above and rounded for a snubbing post. The center piles in certain clusters will also be equipped with line

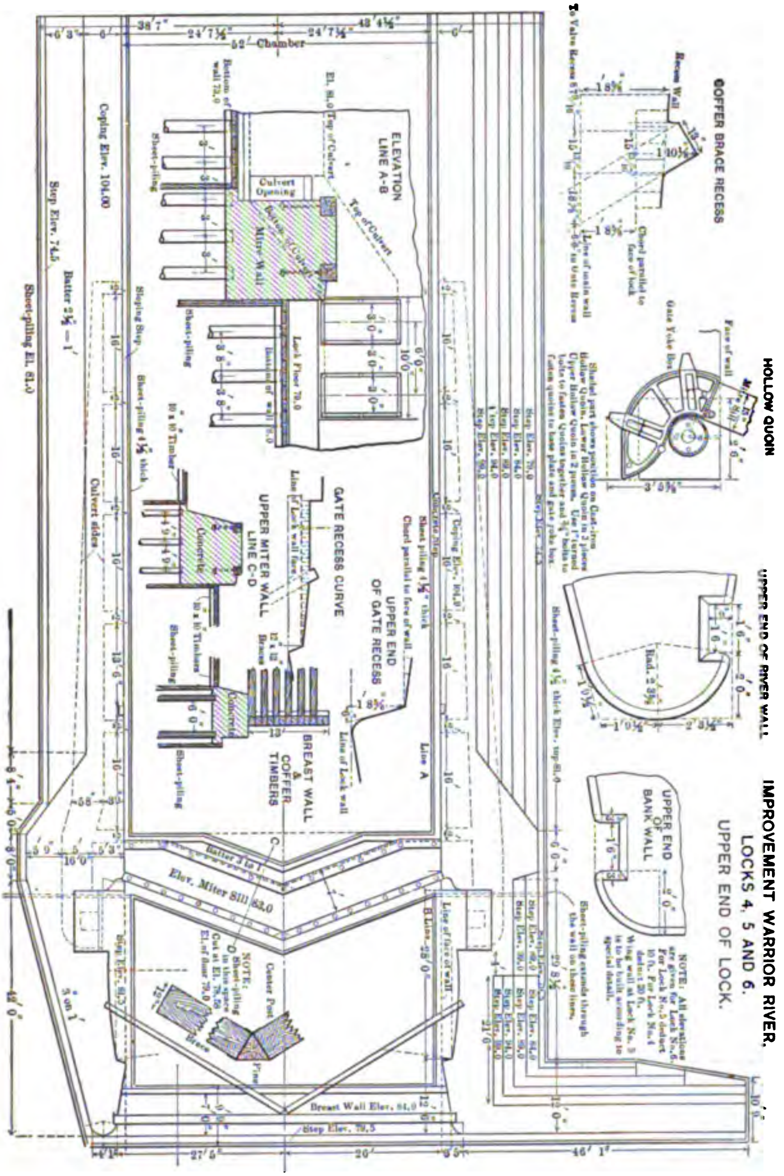

IMPROVEMENT WARRIOR RIVER.
LOCKS 4, 5 AND 6.
UPPER END OF LOCK.
COFFER BRACE RECESS
HOLLOW QUOIN
UPPER END OF RIVER WALL
UPPER END OF BANK WALL
ELEVATION LINE A-B
GATE RECESS CURVE
UPPER MITER WALL LINE C-D
UPPER END OF GATE RECESS
BREAST WALL & COFFER TIMBERS
52' Chamber
Coping Elev. 104.00
Elev. Miter Sill 83.0
Breast Wall Elev. 84.0
Step Elev. 79.5

FIG. 14.

hooks for use at varying stages of water. That part of the piles above low water will be all heart, squared, 12 x 12 ins., with rounded corners. Below low water the piles will be left round. There will be six clusters above the lock, the first four being in line with the river wall and spaced 30 ft. between centers. The other two clusters flare from this line 10°, and are spaced 90 ft. between centers. The greater spacing of these two clusters is to facilitate the passage of drift. The other clusters are spaced closer, because the suck of the dam is greater near the lock. There will be four clusters below the lock in line with the bank wall, the first cluster 30 ft. from the end of lock wall and the others spaced 60 ft. from center to center. These clusters will keep vessels in proper position for entering the lock, and barges can be tied to them when fleets are locked in sections (see Fig. 16).

Engineering Features—Black Warrior System.

Plans.—Sections and plans of Dams Nos. 1, 2 and 3, and detailed drawings of Lock and Dam No. 4, are shown in Figs. 17 to 20. The site of Lock No. 4, looking down stream, is shown on Plate XIX, Fig. 1; the lower end of Lock No. 1, and Dam No. 1, are shown on Plate XIX, Fig. 2.

Lift, Guard, Etc.—The lift at Lock No. 1 will be 10 ft. when the next dam below is built. The guard is 13 ft. and the length of the dam 339 ft. The lift of Lock No. 2 is 8.5 ft., the guard is 15.5 ft., and the length of the dam 409 ft. The lift at Lock No. 3 is 10.5 ft., the guard is 15 ft., and the length of the dam 650 ft. Generally, these dams are navigable when the lock walls are submerged. In 1897, during one of the most rapid rises which has occurred since the dams were built, the fall over the dams, just as the lock walls became submerged, was observed as follows: Dam No. 1, 1.14 ft. fall, river rising 2 ft. per hour; Dam No. 2, 2.10 ft. fall, river rising 2 ft. per hour; and Dam No. 3, 1.40 ft. fall, river rising 1 ft. per hour. In each case the dams became navigable in a few hours after the locks were submerged. While this same rise was subsiding, just as the lock walls emerged, the fall over Dams Nos. 1, 2 and 3 was 0.10 ft., 0.15 ft., and 0.20 ft., respectively.

The lift at Lock No. 4 will be 12 ft., the guard 12 ft., and the length of the dam 640 ft. Owing to the character and steepness of the stream here and above, it was not considered practicable to make the dams

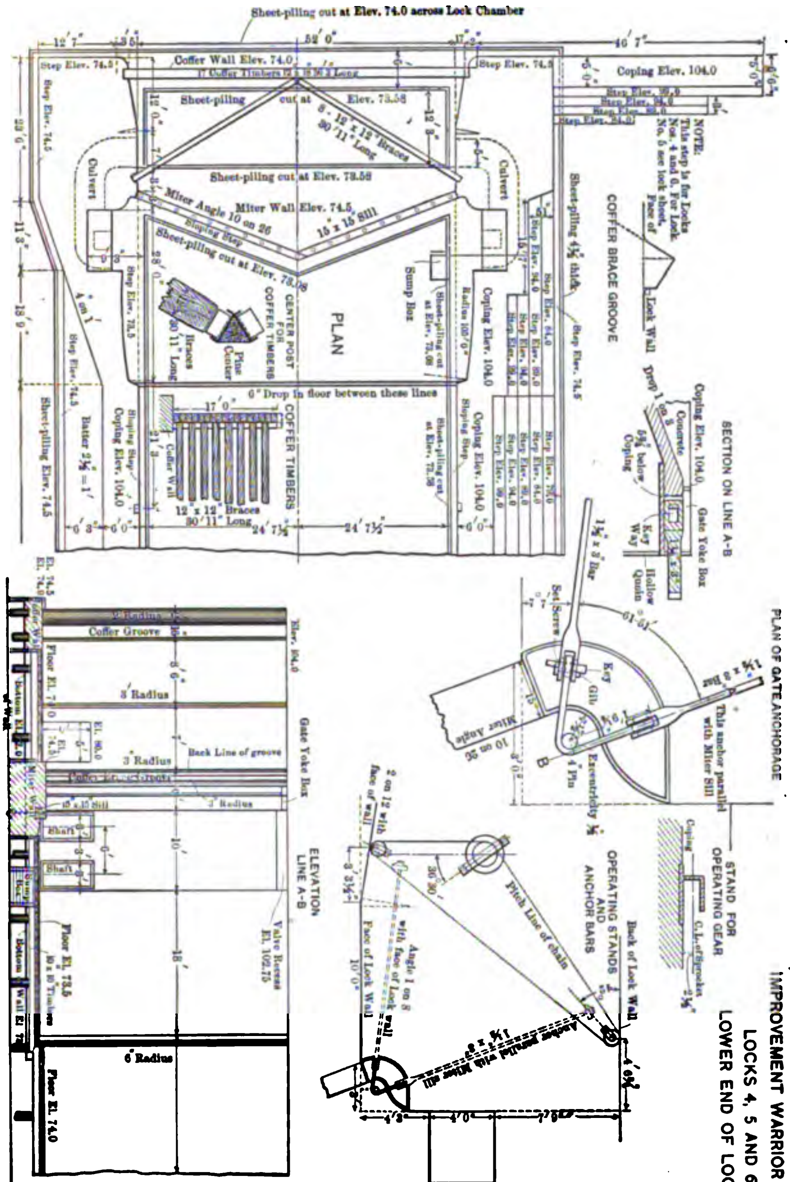


FIG. 15.

IMPROVEMENT WARRIOR RIVER, LOCKS 4, 5 AND 6. LOWER END OF LOCK.

navigable when the locks are submerged. The lock walls will be about 10 ft. below ordinary high water and about 19 ft. below extreme flood, and will never be submerged except for a few days at a time. During such times the river would be unsafe for navigation, under any circumstances, and all traffic should seek harbors of refuge.

Masonry.—The walls and dams are built of sandstone quarried in the vicinity of the locks along the banks of the river and in the river bed. The stone for Lock and Dam No. 3 was quarried from the river bed just below the lock under what is now the channel for vessels. This quarry was in a reef just above falls about 7 ft. high, and was exposed by building a dam and training wall out from the shore and down to the falls. It covered about 2 acres of the river bed, and was 12 to 18 ft. deep. It was operated during the low-water period, only, and was drained with two 8-in. pulsometers. It yielded a hard, durable sandstone at a very reasonable cost, as there was no stripping.

All masonry is founded on bed-rock, the exposed faces of the lock and abutment walls being built of cut stone and the interior and back, where not exposed, of uncut rubble. The foundations for the faces of the lock walls and culverts are excavated to the grade of the lock floor, the rear of the walls being stepped up on the original bed-rock, only loose and soft rock being removed. Weep holes for drainage are left in the lower wing of the abutment and in the lower wing of the lock bank wall; also, a portion of the rear of the lock bank-wall is built of dry rubble thoroughly bonded into the mortar part of the wall. This serves as a drain for the back-filling, and reduces the cost of the wall without materially reducing its weight. Pointing is done as the work progresses, so that the pointing and other mortar may set together.

A small quantity of Louisville natural cement, 1 of cement to 2 of sand, was used in beginning Lock No. 1. With this exception, Portland cement has been used throughout. At Locks Nos. 1, 2 and 3 the cement was measured loose and the face stones were set in mortar composed of 1 of cement and 3 of sand. Some of the rubble was built up in similar mortar, some was grouted, and some had the interstices filled with concrete composed of 1 of cement, 3 of sand and 5 of broken stone, rammed in place. At Lock No. 4 the cement is measured packed, and the face stones are set in mortar composed of 1 of cement and 3 of

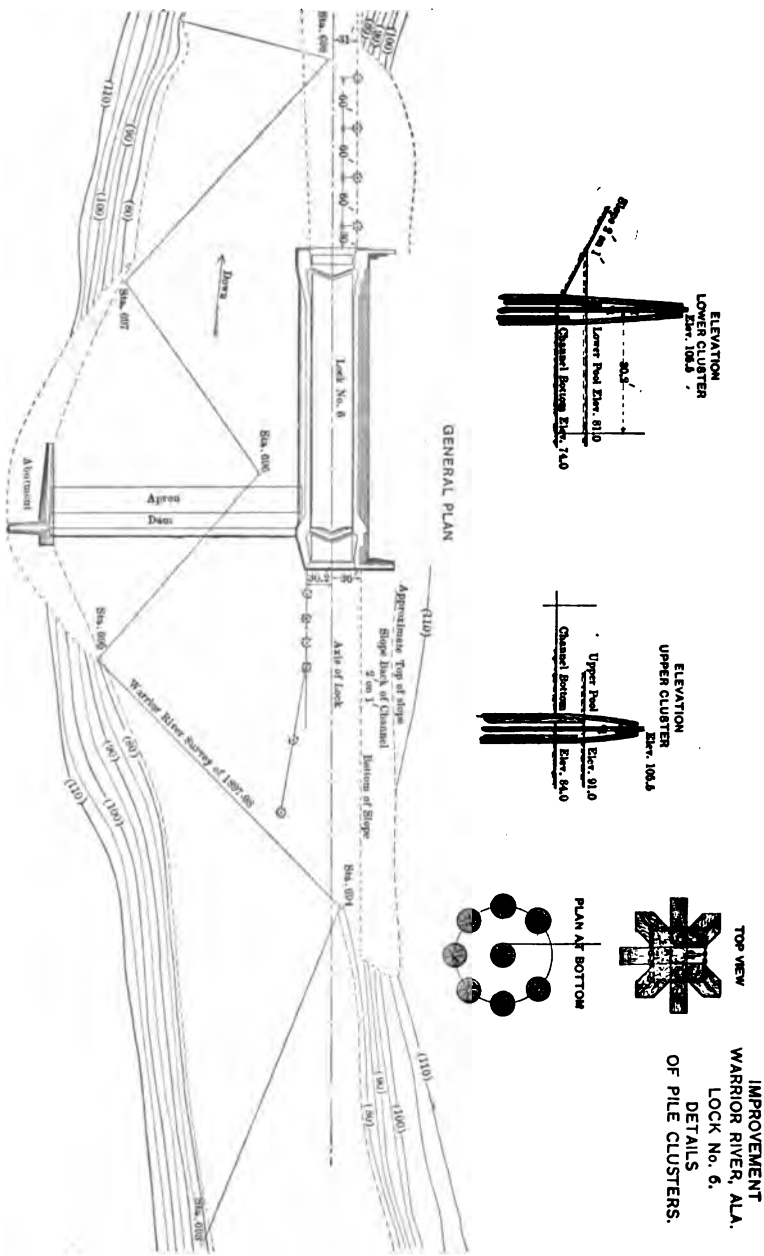

IMPROVEMENT
WARRIOR RIVER, ALA.
LOCK No. 6.
DETAILS
OF PILE CLUSTERS.
ELEVATION
LOWER CLUSTER
Lower Pool Elev. 81.0
Channel Bottom Elev. 74.0
ELEVATION
UPPER CLUSTER
Elev. 108.5
Upper Pool
Elev. 91.0
Channel Bottom
Elev. 84.0
TOP VIEW
PLAN AT BOTTOM
GENERAL PLAN
Lock No. 6
Apron
Dam
Abutment
Down
Axis of Lock
Approximate Top of slope
Slope Back of Channel
2 on 1
Bottom of Slope
Warrior River Survey of 1887-88

Fig. 16.

sand. The rubble is bedded and built up in concrete composed of 1 of cement, 3 of sand, and 5 of clean pebbles, the concrete being thoroughly rammed into the interstices. The stability of the walls is about the same as those for the Warrior locks. See Fig. 20.

Dams.—Movable dams were not considered for the Black Warrior System, because open-river navigation is not practicable on this portion of the stream under any conditions. Dams Nos. 1, 2 and 3 are of the rock-fill type, without mortar or core-wall. The down-stream face is composed of large roughly dressed stones, laid in steps and dowelled together. A timber crib is built into the up-stream face and sheathed. A timber wale is anchor-bolted to the top course of dressed stones, and a sloping crest of timber is drift-bolted to this wale and to the top of the crib in the up-stream face. These three dams were built during the low-water seasons, without coffer-damming. A floating derrick was used above the dams, and stationary derricks erected on the bed-rock reefs were used below the dams and were moved ahead as the building progressed. The stone for Dams Nos. 1 and 2 was delivered by barge, and for Dam No. 3 by rail, a track being laid on stone-filled cribs along the toe of the dam. The low-water flow of the stream ran through the rock-fill dams until all the stone-work and the timber crest were in place. Then the vertical sheathing on the up-stream face and the filling above the dams were placed, and the pools filled in a short time.

These dams are very cheap, but not altogether satisfactory. The filling above the dams is not permanent, and has to be renewed from time to time. The leakage is so great that at times it is difficult to keep the pools full. On certain stages there is a strong "back lash" below the dams, which holds and tosses drift sometimes for a day or two before it can get away. Saw logs, and other heavy drift, at such times, if they come back "end on" in the "back lash," dive when they reach the sheet of water falling over the crest, and strike the step stones in the down-stream face of dams like so many battering rams. This action of the drift made several large breaches in the down-stream faces of the dams, there being no dowels in the face stones when the dams were first built. Afterward, two 1¼-in. dowel pins were put through each face stone into the stones below. No large breaches, but several small ones, have occurred since the face stones were dowelled. The crests of these dams have settled as much

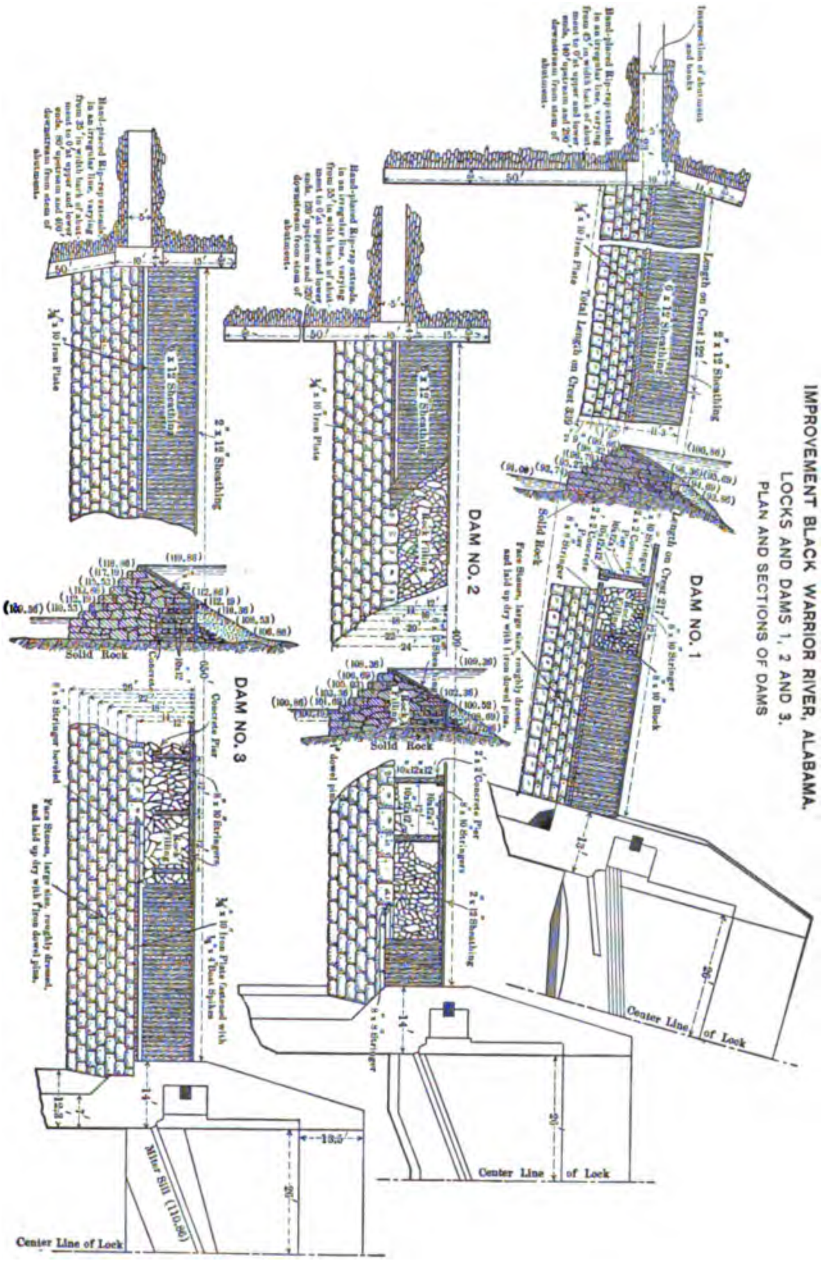

IMPROVEMENT BLACK WARRIOR RIVER, ALABAMA.
LOCKS AND DAMS 1, 2 AND 3.
PLAN AND SECTIONS OF DAMS
DAM NO. 1
DAM NO. 2
DAM NO. 3
Solid Rock
Center Line of Lock

FIG. 17.

as 4 ins. in places, and the bed-rock, below the dams which have no aprons, is wearing from the action of the water and drift. It is probably just a question of time when these dams will have to be rebuilt or extensively repaired. See Fig. 17.

The objections to this type of dam led to a different design for Dam No. 4, which is being built of rubble masonry in mortar and concrete, but with timber coping to reduce cost. The face stones are laid in mortar composed of 1 of packed cement and 3 of sand. The interior stones are bedded and built up in concrete composed of 1 of packed cement, 3 of sand and 5 of clean pebbles. Both faces are carefully pointed as the work progresses. The down-stream face is built of large stones roughly dressed, with a straight batter of 6 ins. per foot. It is thought that this type of dam will be tight and will suffer little injury from drift playing below; also, the down-stream toe is carried well down into bed-rock, which will have to wear to the bottom of the toe before the dam can begin to undermine. Thus the bed-rock will be utilized as an apron, and should it wear enough to endanger the dam it can be replaced with an artificial apron. It is probable that a concrete dam of ogee section would be better and cheaper for such conditions, and will be built with the locks projected above Dam No. 4. See Fig. 18.

Gates.—The gates for Locks Nos. 1, 2 and 3 are built of steel, and are of the mitering, horizontal-girder type, with a single skin of ¼-in. plates on the water side. The girders are 20-in. I-beams, with a ¾-in. camber against the water pressure. The beams are all the same size, the spacing decreasing from the top to the bottom of the gate to provide for the increase of pressure, and are fastened to the miter and heel posts with connecting angles. The bottom beam bears against the miter-sill cushion, the bearing surface of which has a ¾-in. camber to fit the beam.

The miter posts are of oak, backed with a steel plate $\frac{5}{8}$ in. thick. The heel posts are of cast iron, and are similar to those for the Warrior locks, but larger in diameter, owing to the greater depth of the ends of the girders. The top gudgeon is of soft steel, and is turned and pressed into the top of the heel post, which is flush with the coping. The yoke, therefore, comes above the coping, and is connected with turnbuckles to the anchorages, which are bolted to the top of the wall and partly countersunk. The operating lever is

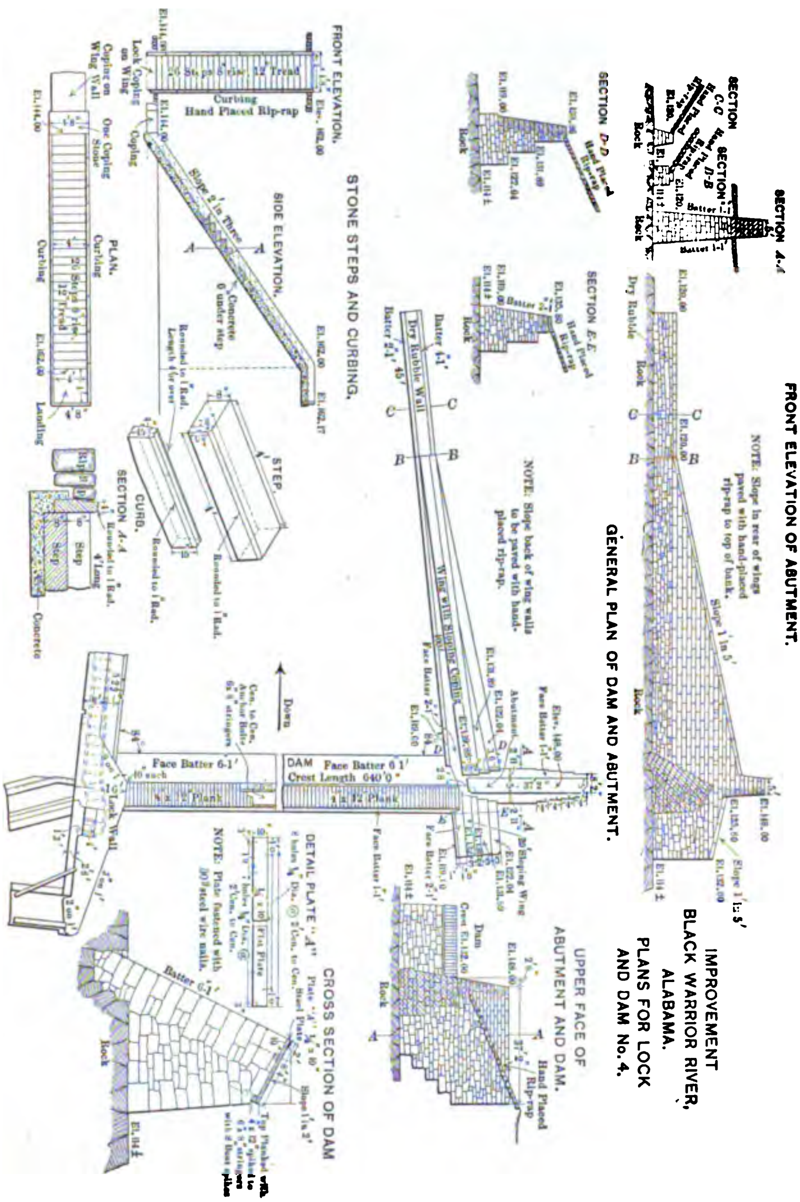

IMPROVEMENT BLACK WARRIOR RIVER, ALABAMA.
PLANS FOR LOCK AND DAM No. 4.
FRONT ELEVATION OF ABUTMENT.
GENERAL PLAN OF DAM AND ABUTMENT.
UPPER FACE OF ABUTMENT AND DAM.
CROSS SECTION OF DAM
STONE STEPS AND CURBING.
FRONT ELEVATION.
SIDE ELEVATION.
PLAN.
STEP.
CURB.
SECTION A-A
SECTION D-D
SECTION E-E
DETAIL PLATE "A"

Fig. 18.

fastened to the gate above the yoke, and slopes downward so that the trolley slot at the outer end hangs close to the coping. Other features of these gates are similar to those of the Warrior locks.

The gates for Lock No. 4 are similar in design to those for the Warrior locks, except that the anchorages are countersunk and bolted to the top of the wall, instead of being built into the masonry.

Valves.—Two kinds of valves were tried at Lock No. 1. One was a flexible curtain valve of asbestos rubber cloth, stiffened on the culvert side with horizontal iron slats slightly separated and riveted to the cloth. This valve was lifted from the bottom, peeling up, instead of rolling, by means of gearing on the walls and counterweights working in wells. These valves were used for several years, but did not prove durable or satisfactory, and were finally replaced with valves similar to those for the Warrior locks.

The other valve used at Lock No. 1 is a cast-iron, balanced gate with a vertical axis. The casting is in one piece, with horizontal stiffening ribs, and is cast around the steel center shaft, the ends of which are turned for journals. The frame consists of oak sills bolted into recesses in the masonry and lined with wrought-iron valve bearings. The valve revolves in cast journal boxes bolted to the oak sills. A steel rod, with a socket on the bottom end fitting over the square top of the valve shaft, extends up to the top of the wall, where it is revolved to open or close the valve by a simple lever fastened to the top of the rod. This same valve is in use at Locks Nos. 2 and 3, and has proved fairly satisfactory. The journal boxes and frame linings work loose, and wear more or less, and several of the valves were cracked shortly after being erected, probably due to water hammer caused by closing the valves suddenly against a head of water. Also, the valve cannot be operated as smoothly with the single lever as with the worm gear. The steel valve operated by the worm gear is considered, on the whole, safer and more durable.

The valves for Lock No. 4 are similar in design to those for the Warrior locks.

Coffer Timbers, Etc.—When Locks Nos. 1, 2 and 3 were built, light needle-dams, extending about 2 ft. above the pool level, were provided at the upper ends, but no provision for coffer-dams was made at the lower ends. The erection of the needle-dam exposes the upper gates and valves, which are entirely above the lower pool level. When repairs

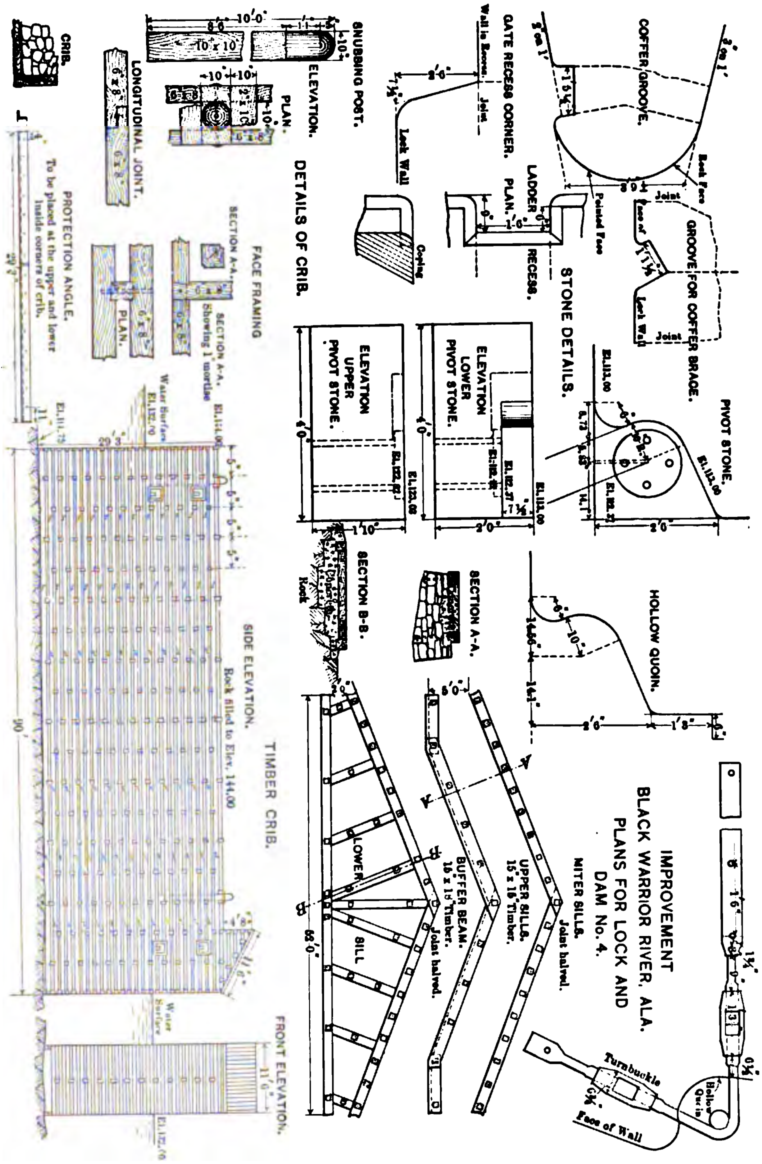

IMPROVEMENT
BLACK WARRIOR RIVER, ALA.
PLANS FOR LOCK AND
DAM No. 4.
GATE ANCHORAGE.
Turnbuckle
Face of Wall
MITER SILLS.
UPPER SILLS.
BUFFER BEAM.
LOWER
SILL
HOLLOW QUOIN.
PIVOT STONE.
COFFER GROOVE.
GROOVE FOR COFFER BRACE.
STONE DETAILS.
GATE RECESS CORNER. PLAN.
LADDER RECESS.
ELEVATION LOWER PIVOT STONE.
ELEVATION UPPER PIVOT STONE.
SECTION A-A.
SECTION B-B.
SNUBBING POST.
ELEVATION.
PLAN.
DETAILS OF CRIB.
FACE FRAMING
LONGITUDINAL JOINT.
PROTECTION ANGLE.
To be placed at the upper and lower inside corners of crib.
CRIB.
TIMBER CRIB.
SIDE ELEVATION.
FRONT ELEVATION.

FIG. 19.

are needed to the lower gates and valves, or when the lock chambers need cleaning out, there being no dredge available, the practice has been to draw each pool down at low water through the lock below, raise the needle-dam at the upper end, put in a low, cheap, temporary coffer-dam of clay or canvas at the lower end, and pump out. The objection to this method is that it is only available at low water, and a very slight rise will flood the pool below, while a rise of over 2 ft. will flood the needle-dam above. This renders repair work quite precarious. Also, in order to drain a pool, it is necessary to lash open the gates of the lock below and turn the river through the lock. This leaves the lock in bad condition in case of a sudden rise. One gate has recently been greatly injured under these circumstances by being torn from its lashings and slammed against the miter sill by the current. It had to be taken down, repaired, and re-erected.

The pools below Dams Nos. 2 and 3 are quite short, and can be drained quickly at low water. So far, there has been an open river below Dam No. 1, but the next dam below, Warrior No. 6, will probably be built during 1902. This will make a pool 46 miles long below Dam No. 1, which cannot be drained quickly, or without damage to commerce, even at low water. Therefore, during 1901, provision was made at the lower end of Lock No. 1 for a permanent coffer-dam, 5 ft. above the pool level and otherwise similar to those for the Warrior locks. Similar coffer-dams will probably be provided, later, at the lower ends of Locks Nos. 2 and 3.

The needle-dams in use at Locks Nos. 1, 2 and 3 are erected on masonry breast walls extending across the heads of the locks and up to within about 7 ft. of the pool level. The needles are each 4 ins. wide, and are placed against two sills. The bottom sill is built and anchored into the masonry of the breast wall. The top sill rests at each end in recesses cut in the faces of the lock walls, and is supported at intervals of about 7½ ft. by steel trestles anchored to the breast wall and hinged so that when not in use they lie flat upon it. The needles, when in place, slope down stream at an angle of about 20° from the vertical. These needle-dams are quite simple and efficient, and are easily maneuvered. The principal objection to them is that they extend only 2 ft. above the pool level.

At Lock No. 4, coffer timbers at both ends, similar to those for the Warrior locks, are provided.

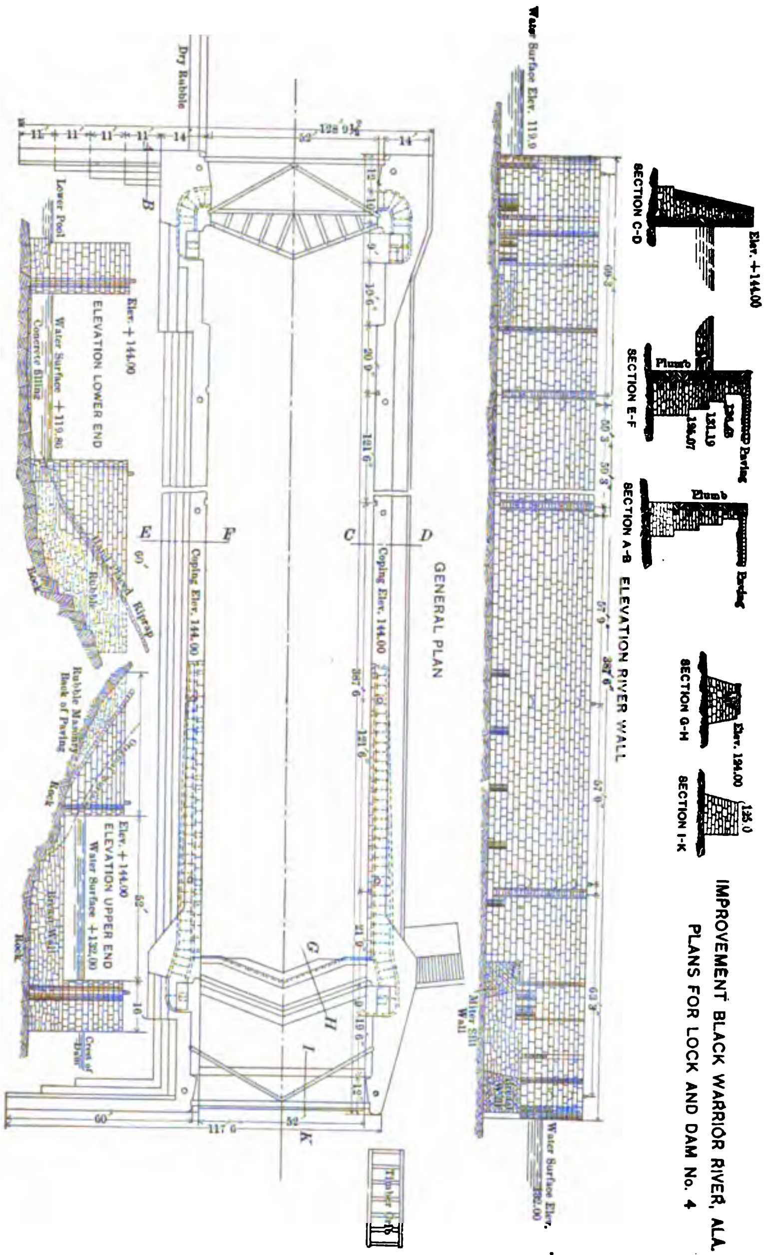

IMPROVEMENT BLACK WARRIOR RIVER, ALA.
PLANS FOR LOCK AND DAM No. 4
SECTION C-D
SECTION E-F
SECTION A-B
SECTION G-H
SECTION I-K
ELEVATION RIVER WALL
GENERAL PLAN
ELEVATION LOWER END
ELEVATION UPPER END
Coping Elev. 144.00
Water Surface Elev. 119.9
Dry Rubble
Lower Pool
Miter Sill
Timber Crib

FIG. 20.

Bank Protection.—At Locks Nos. 1, 2 and 3 all bank protection consists of hand-placed rip-rap, 12 ins. thick. It covers the horizontal space between the bank-wall wings and most of the slope back of these wings, and the sloping banks for a short distance above and below each lock; also the sloping banks for short distances above and below each lock ; also the sloping banks for a short distance above and for about 300 ft. below each abutment. Immediately back of the locks and abutments this protection extends well up toward the top of the slope, but tapers down toward the low-water line at the lower end. This rip-rap slips in places, after floods, and requires more or less repairs each season, but, on the whole, has served its purpose well. In places it is now covered with willows and other vegetation, which help to hold it in place. The banks here consist largely of clay, and do not erode so readily as the alluvial banks of the Warrior.

The bank protection at Lock No. 4 will be similar to that at Locks Nos. 1, 2 and 3, except that well-shaped stone paving 15 ins. thick will be used on the horizontal space between the bank-wall wings.

Guard Cribs.—When Locks Nos. 1, 2 and 3 were built, a single guard crib, 90 ft. long and 11½ ft. wide, was placed above and in line with the river wall at each lock, a space of 10 ft. being left between the crib and the lock wall for the passage of drift. The top of the crib was level with the coping of the lock, and a sloping drift guard on the upper end of the crib extended 5 ft. higher. The cribs were built of 6 x 8-in. yellow pine, with cross-pieces at intervals of 5 ft., drift-bolted together, and filled with "one man" stone.

At certain stages the suck of the dam causes a strong current around the head of the crib. This caused the wreck of a towboat and several barges in February, 1901, they being drawn over the dam while maneuvering to enter the head of Lock No. 2. To afford better protection to traffic, four additional cribs, 24 ft. long and 12 ft. wide, with 21-ft. openings between them for drift, are now being built above each of the old cribs. The new cribs are on a line flaring 10° at Locks Nos. 1 and 2, and 15° at Lock No. 3, toward the river from the line of the old crib, and extend the protection to a total distance of 280 ft. above the head of lock. It is probable that, should fleets ever be handled that will require two or more lockages to pass a lock, guard cribs with snubbing posts will be required below and in line with the bank walls, but none have yet been built or provided for.

FIG. 1.—WARRIOR RIVER: SITE OF LOCK NO. 5, LOOKING UP STREAM.

FIG. 2.—WARRIOR RIVER: LOCK NO. 6, SHOWING CONCRETE FORMING.

A single crib, similar to those first built at Locks Nos. 1, 2 and 3, is provided for at Lock No. 4, but it is probable that additional cribs will be needed there also. (See Fig. 19.)

Other Features.—With given lifts, the location of each lock is largely fixed by the profile of the stream, and there is little choice between different sites. As far as practicable, the locks are placed on a convex shore, to secure protection from drift, and straight approaches. No mounds have been built at the Black Warrior locks, because there has been no surplus excavation and the river banks are much higher than at the Warrior locks. The lock floors consist of bed-rock, as left after excavating to grade, and are quite rough. The culverts and other details not mentioned are similar to those described for the Warrior locks.

Cost.

As stated previously, the total cost of these improvements will approximate $5 000 000, or $250 000 per lock and dam.

Tombigbee System.—The work on Lock and Dam No. 1 is about three-fifths completed. No detailed estimates of the cost of completing this and building Locks and Dams Nos. 2 and 3 have yet been made. The cost of concrete in place at Lock No. 1 was about $6.34 per cubic yard, under fair working conditions, but this did not include the cost of coffer-dams and other incidental expenses.

Warrior System.—The estimated cost of Locks and Dams Nos. 1, 2 and 3 is $874 000, as itemized in Table No. 2.

TABLE No. 2.

Lock No. 1. Kind of work and material.	Measure.	Quantity.	Price.	Amount.
Concrete	Cubic yards.	12 000	$7.50	$90 000
Excavation	"	260 000	0.35	91 000
Gravel filling	"	1 000	1.00	1 000
Stone filling	"	7 000	2.50	17 500
Rip-rap	"	4 000	2.50	10 000
Puddling	"	100	1.50	150
Miter sills	Feet, B. M.	4 000	50.00	200
Dam timber	"	320 000	30.00	9 600
Apron timber	"	110 000	25.00	2 750
Floor timber	"	116 000	40.00	4 640
Sheathing	"	20 000	20.00	400
Sheet-piling	"	550 000	40.00	22 000
Foundation piles	Linear feet.	50 000	0.30	15 000
Heart piles	"	6 000	0.35	2 100
Drain pipes	"	500	0.50	250
Grubbing and clearing	Complete.			1 000
Coffer-dams				10 000
				$277 590
Purchase of sites				2 000
Gates, valves and irons				15 000
Buildings				5 000
Engineering and incidentals				33 410
Total				$333 000
Lock No. 2.				
Concrete	Cubic yards.	12 000	$7.50	$90 000
Excavation	"	135 000	0.35	47 250
Gravel filling	"	1 000	1.00	1 000
Stone filling	"	4 000	2.50	10 000
Rip-rap	"	2 900	2.50	7 250
Puddling	"	100	1.50	150
Miter sills	Feet, B. M.	4 000	50.00	200
Dam timber	"	195 000	30.00	5 850
Apron timber	"	66 000	25.00	1 650
Floor timber	"	116 000	40 00	4 640
Sheathing	"	20 000	20.00	400
Sheet-piling	"	465 000	40.00	18 600
Foundation piles	Linear feet.	48 000	0.30	14 400
Heart piles	"	6 000	0.35	2 100
Drain pipe	"	500	0.50	250
Grubbing and clearing	Complete.			1 000
Coffer-dams				8 000
				$212 740
Purchase of sites				500
Gates, valves and irons				15 000
Buildings				5 000
Engineering and incidentals				26 760
Total				$260 000

TABLE No. 2—(*Continued*).

Lock No. 3. Kind of work and material.	Measure.	Quantity.	Price.	Amount.
Concrete	Cubic yards.	12 000	$7.50	$90 000
Excavation	"	175 000	0.35	61 250
Gravel filling	"	1 000	1.00	1 000
Stone filling	"	3 600	2.50	9 000
Rip-rap	"	3 600	2.50	9 000
Puddling	"	100	1.50	150
Miter sills	Feet, B. M.	4 000	50.00	200
Dam timber	"	195 000	30.00	5 850
Apron timber	"	66 000	25.00	1 650
Floor timber	"	116 000	40.00	4 640
Sheathing	"	20 000	20.00	400
Sheet-piling	"	520 000	40.00	20 800
Foundation piles	Linear feet.	55 000	0.30	16 500
Heart piles	"	6 000	0.35	2 100
Drain pipe	"	500	0.50	250
Grubbing and clearing	Complete.			1 000
Coffer-dams				8 000
				$231 790
Purchase of sites				500
Gates, valves and irons				15 000
Buildings				5 000
Engineering and incidentals				28 710
Total				$281 000
RECAPITULATION.				
Lock No. 1				$333 000
Lock No. 2				260 000
Lock No. 3				281 000
Grand total				$874 000

The Bids received for Locks and Dams Nos. 4, 5 and 6 are shown in Table No. 3.

Miter sills	Feet, B. M.	4 000	$14.00	$176.00	$50.00	$900.00	$45.00	$180.00	$50.00	$900.00	$36.00	$144.00
Dam timber	"	171 000	29.00	4 959.00	37.50	6 412.50	32.50	5 557.50	30.00	5 130.00	29.00	4 959.00
Apron timber	"	67 000	24.50	1 641.50	25.00	1 675.00	30.00	2 010.00	25.00	1 675.00	19.20	1 286.40
Floor timber	"	112 000	30.00	3 360.00	30.00	3 360.00	35.00	3 920.00	35.00	3 920.00	40.00	4 480.00
Sheathing	"	20 000	20.00	400.00	50.00	1 000.00	30.00	600.00	20.00	400.00	17.00	340.00
Sheet-piling	"	270 000	50.00	13 500.00	50.00	13 500.00	40.00	10 800.00	50.00	13 500.00	50.00	13 500.00
Foundation piles	Linear feet.	50 000	0.32	16 000.00	0.40	20 000.00	0.25	12 500.00	0.20	10 000.00	0.29	14 500.00
Heart piles	"	2 000	0.34	680.00	1.00	2 000.00	0.50	1 000.00	0.25	500.00	0.30	600.00
Drain pipe	"	500	1.00	500.00	0.60	300.00	0.28	140.00	0.50	250.00	0.50	250.00
Grubbing and clearing	Complete.	....	....	200.00	....	2 000.00	......	4 600.00	......	1 000.00	......	240.00
Totals	....	....	....	$162 856.50	....	$204 072.50	......	$182 632.50	......	$145 179.00	......	$132 135.40
Alternative quantities:												
Stone filling	Cubic yards.	3 600	$2.00	$7 200.00	$5.00	$18 000.00	$2.50	$9 000.00	$3.60	$12 960.00	$1.14	$4 104.00
Stone paving	"	1 650	7.00	11 550.00	5.50	9 075.00	6.50	10 725.00	3.60	5 940.00	2.70	4 455.00
Rip-rap (hand-placed)	"	1 200	2.50	3 000.00	5.25	6 300.00	3.50	4 200.00	3.10	3 720.00	1.20	1 440.00

Lock and Dam No. 6.

Concrete	Cubic yards.	11 200	$7.50	$84 000.00	$10.00	$112 000.00	$9.00	$100 800.00	$6.48	$72 576.00	$6.00	$67 200.00
Excavation	"	76 000	0.50	38 000.00	0.50	38 000.00	0.50	38 000.00	0.40	30 400.00	0.31	23 560.00
Gravel filling	"	4 000	0.75	3 000.00	0.70	2 800.00	1.00	4 000.00	1.00	4 000.00	0.42	1 680.00
Puddling	"	100	1.50	150.00	1.25	125.00	1.25	125.00	2.00	200.00	0.60	60.00
Mattress work	Square yards.	5 000	0.90	4 500.00	1.00	5 000.00	1.00	5 000.00	0.50	2 500.00	0.48	2 400.00
Miter sills	Feet, B. M.	4 000	44.00	176.00	50.00	200.00	45.00	180.00	50.00	200.00	36.00	144.00
Dam timber	"	155 000	29.00	4 495.00	35.00	5 425.00	32.50	5 037.50	30.00	4 650.00	29.00	4 495.00
Apron timber	"	67 000	24.50	1 641.50	25.00	1 675.00	30.00	2 010.00	25.00	1 675.00	19.20	1 286.40
Floor timber	"	112 000	30.00	3 360.00	30.00	3 360.00	35.00	3 920.00	35.00	3 920.00	40.00	4 480.00
Sheathing	"	20 000	20.00	400.00	50.00	1 000.00	30.00	600.00	20.00	400.00	17.00	340.00
Sheet-piling	"	275 000	50.00	13 750.00	60.00	16 500.00	40.00	11 000.00	50.00	13 750.00	47.00	12 925.00
Foundation piles	Linear feet.	55 000	0.32	17 600.00	0.50	27 500.00	0.25	13 750.00	0.20	11 000.00	0.29	15 950.00
Heart piles	"	2 100	0.34	714.00	1.00	2 100.00	0.50	1 050.00	0.25	525.00	0.30	630.00
Drain pipe	"	500	1.00	500.00	0.60	300.00	0.28	140.00	0.50	250.00	0.50	250.00
Grubbing and clearing	Complete.	....	....	200.00	....	4 000.00	......	4 600.00	......	1 000.00	......	240.00
Totals	....	....	....	$172 486.50	....	$219 985.00	......	$190 212.50	......	$147 046.00	......	$135 640.40

TABLE No. 3.

Lock and Dam No. 4.

Items.	Measure.	Quantity.	No. 1.		No. 2.		No. 3.		No. 4.		No. 5.	
			Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.
Concrete................	Cubic yards.	11 300	$7.50	$84 750.00	$11.00	$124 300.00	$9.50	$107 350.00	$6.48	$73 224.00	$5.95	$67 235.00
Excavation..............	"	140 000	0.50	70 000.00	0.40	56 000.00	0.50	70 000.00	0.35	49 000.00	0.28	39 200.00
Gravel filling............	"	3 900	0.75	2 925.00	1.00	3 900.00	1.00	3 900.00	1.00	3 900.00	0.42	1 638.00
Puddling.................	"	100	1.50	150.00	1.25	125.00	1.25	125.00	2.00	200.00	0.60	60.00
Mattress work...........	Square yards.	6 200	0.90	5 580.00	1.00	6 200.00	1.00	6 200.00	0.50	3 100.00	0.48	2 976.00
Miter sills................	Feet, B. M.	4 000	44.00	176.00	50.00	200.00	45.00	180.00	50.00	200.00	36.00	144.00
Dam timber.............	"	155 000	29.00	4 495.00	40.00	6 200.00	32.50	5 037.00	30.00	4 650.00	29.00	4 495.00
Apron timber...........	"	67 000	24.50	1 641.50	27.50	1 842.50	30.00	2 010.00	25.00	1 675.00	19.20	1 286.40
Floor timber............	"	112 000	30.00	3 360.00	32.50	3 640.00	35.00	3 920.00	35.00	3 920.00	40.00	4 480.00
Sheathing...............	"	20 000	20.00	400.00	50.00	1 000.00	30.00	600.00	20.90	400.00	17.00	340.00
Sheet-piling.............	"	275 000	50.00	13 750.00	60.00	16 500.00	40.00	11 000.00	50.00	13 750.00	50.00	13 750.00
Foundation piles........	Linear feet.	44 000	0.32	14 080.00	0.40	17 600.00	0.25	11 000.00	0.20	8 800.00	0.29	12 760.00
Heart piles..............	"	2 000	0.34	680.00	1.00	2 000.00	0.50	1 000.00	0.25	500.00	0.30	600.00
Drain pipe...............	"	500	1.00	500.00	0.60	300.00	0.28	140.00	0.50	250.00	0.50	250.00
Grubbing and clearing..	Complete.	....	....	200.00	....	5 000.00	......	4 600.00	......	1 000.00	......	240.00
Totals.............	....	....	....	$202 687.50	....	$244 807.50	......	$227 062.50	......	$164 569.00	......	$149 454.40
Alternative quantities:												
Stone filling...........	Cubic yards.	3 100	$2.00	$6 200.00	$5.00	$15 500.00	$2.50	$7 750.00	$3.75	$11 625.00	$1.14	$3 534.00
Stone paving..........	"	1 150	7.00	8 050.00	5.50	6 325.00	6.50	7 475.00	3.75	4 312.50	2.70	3 105 00
Rip-rap (hand-placed)	"	2 100	2.50	5 250.00	5.25	11 025.00	3.50	7 350.00	3.25	6 825.00	1.20	2 520 00

Lock and Dam No. 5.

Items.	Measure.	Quantity.	No. 1. Price.	No. 1. Amount.	No. 2. Price.	No. 2. Amount.	No. 3. Price.	No. 3. Amount.	No. 4. Price.	No. 4. Amount.	No. 5. Price.	No. 5. Amount.
Concrete................	Cubic yards.	12 300	$7.50	$92 250.00	$10.00	$123 000.00	$9.00	$110 700.00	$6.48	$79 704.00	$6.00	$73 800.00
Excavation..............	"	45 000	0.50	22 500.00	0.50	22 500.00	0.50	22 500.00	0.50	22 500.00	0.32	14 400.00
Gravel filling............	"	4 400	0.75	3 300.00	1.00	4 400.00	1.00	4 400.00	1.00	4 400.00	0.42	1 848.00
Puddling.................	"	100	1.50	150.00	1.25	125.00	1.25	125.00	2.00	200.00	0.60	60.00
Mattress work...........	Square yards.	3 600	0.90	3 240.00	1.00	3 600.00	1.00	3 600.00	0.50	1 800.00	0.48	1 728.00

TABLE No. 3—(*Continued*).

Items.	Measure.	Quantity.	No. 1. Price.	No. 1. Amount.	No. 2. Price.	No. 2. Amount.	No. 3. Price.	No. 3. Amount.	No. 4. Price.	No. 4. Amount.	No. 5. Price.	No. 5. Amount.
Alternative quantities:												
Stone filling...........	Cubic yards.	3 200	$2.00	$6 400.00	$4.00	$12 800.00	$2.50	$8 000.00	$3.50	$11 200.00	$1.14	$3 648.00
Stone paving..........	"	950	7.00	6 650.00	4.50	4 275.00	6.50	6 175.00	3.50	3 325.00	2.70	2 565.00
Rip-rap (hand-placed)	"	1 700	2.50	4 250.00	4.25	7 225.00	3.50	5 950.00	3.00	5 100.00	1.20	2 040.00

Summary.

Items.	No. 1. Price.	No. 1. Amount.	No. 2. Price.	No. 2. Amount.	No. 3. Price.	No. 3. Amount.	No. 4. Price.	No. 4. Amount.	No. 5. Price.	No. 5. Amount.
Totals of bids for Lock and Dam No. 4.............	....	$202 687.50	....	$244 807.50	......	$227 062.50	......	$164 569.00	......	$149 454.40
Totals of bids for Lock and Dam No. 5.............	....	162 856.50	....	204 072.50	......	182 632.50	......	145 179.00	......	132 135.40
Totals of bids for Lock and Dam No. 6.............	....	172 486.50	....	219 985.00	......	190 212.50	......	147 046.00	......	135 640.40
Total bid for all three locks and dams........	....	$538 030.50	....	$668 865.00	......	$599 907.50	......	$456 794.00	......	$417 230.20

The work was let to the lowest bidders, at the prices given in bid No. 5. The latest estimate of the total cost of these three locks and dams is $616 793, itemized as follows:

Contract with lowest bidders..	$458 869
Purchase of sites..	1 524
Gates, valves and irons..	45 400
Buildings..	15 000
Engineering and incidentals..	96 000
Total..	$616 793

This will make a total cost of $1 490 793, for the Warrior System of six locks and dams.

Black Warrior System.—The total cost of Locks and Dams Nos. 1, 2 and 3, including local office expenses, but not including office expenses at the district headquarters in Mobile, was $541 215.57, itemized as in Table No. 4.

TABLE No. 4.

Lock and Abutment No. 1.

(Lock masonry, 9 762 cu. yds.; abutment masonry, 325 cu. yds.)

Item.	Measure.	Quantity.	Cost.	Rate, per unit.
Stone quarried	Cubic yards.	10 087	$34 400.96	$3.410+
Stone cut	"	3 530	37 637.27	10.662+
Masonry laid, including cement	"	10 087	25 474.07	2.525+
Earth excavation	"	10 809	3 016.99	0.279+
Rock excavation	"	3 778	5 014.38	1.327+
Earth filling	"	4 500	1 145.65	0.254+
Rock filling	"	2 500	1 238.98	0.495+
Paving, 12 ins. thick	Square yards.	6 774	2 199.52	0.222+
Turfing	"	3 132		
Gates and valves			12 010.50	
Coffer-dam and pumping			8 555.54	
Handling and hauling			20 273.22	
Boats and buildings			4 518.44	
Track and roads			10 882.29	
Tools and plant			28 535.18	
Engineering and superintendence			19 404.90	
Incidentals			6 771.01	
Total			$221 078.90	

Dam No. 1.

(Dam 10 ft. high, 339 ft. long, and 21 ft. width of base.)

Item.	Measure.	Quantity.	Cost.	Rate, per unit.
Lumber and iron	Feet, B. M.	36 238	$1 010.65	$27.889+
Carpenter work	"	36 238	336.30	9.280+
Stone quarried	Cubic yards.	1 467	5 003.09	3.410+
Stone, rough-dressed	"	360	1 059.41	2.942+
Masonry laid, dry rubble	"	1 467	1 243.11	0.847+
Earth excavation	"	329	60.04	0.182+
Filling above dam	"	502	425.00	0.846+
Handling and hauling			465.22	
Track and roads			100.13	
Tools and plant			554.90	
Engineering and superintendence			477.04	
Incidentals			143.73	
Total			$10 878.62	

Guard Crib No. 1.

(Guard Crib 29 ft. 10 ins. high, 90 ft. long, and 11 ft. 8 ins. wide.)

Item.	Measure.	Quantity.	Cost.	Rate, per unit.
Lumber and iron	Feet, B. M.	34 453	$470.40	$13.653+
Carpenter work	"	34 453	239.07	6.939+
Filling rock	Cubic yards.	1 640	567.51	0.346+
Total			$1 276.98	

TABLE No. 4—(*Continued*).

Lock and Abutment No. 2.

(Lock masonry, 10 723 cu. yds.; abutment masonry, 559 cu. yds.)

Item.	Measure.	Quantity.	Cost.	Rate, per unit.
Stone quarried	Cubic yards.	11 282	$16 509.14	$1.463+
Stone cut	"	3 595	25 744.53	7.161+
Masonry laid, including cement	"	11 282	21 330.53	1.890+
Earth excavation	"	6 876	1 636.01	0.237+
Rock excavation	"	941	995.57	1.057+
Earth filling	"	6 552	1 351.86	0.206+
Paving, 12 ins. thick	Square yards.	8 367 }	2 039.52	0.217+
Turfing	"	1 021 }		
Gates and valves			9 696.45	
offer-dam and pumping			2 402.10	
Handling and hauling			10 002.62	
Boats and buildings			3 441.87	
rack and roads			9 867.23	
Tools and plant			22 512.68	
Engineering and superintendence			18 841.16	
ncidentals			5 507.40	
Total			$146 880.67	

Dam No. 2.

(Dam 13 ft. high, 410 ft. long, and 24 ft. width of base.)

Lumber and iron	Feet, B. M.	53 556	$850.91	$15.888+
Carpenter work	"	53 556	381.80	7.128+
Stone quarried	Cubic yards.	3 646	3 350.85	0.919+
Stone, rough-dressed	"	373	631.37	1.692+
Masonry laid, dry rubble	"	3 646	1 868.20	0.512+
Earth excavation	"	360	45.85	0.127+
Filling above dam	"	607	401.99	0.662+
Cement			185.00	
Handling and hauling			586.54	
Track and roads			106.48	
Tools and plant			934.03	
Engineering and superintendence			1 081.62	
Incidentals			497.61	
Total			$10 902.25	

Guard Crib No. 2.

(Guard crib 28 ft. 8 ins. high, 90 ft. long, and 11 ft. 6 ins. wide.)

Lumber and iron	Feet, B. M.	33 109	$419.80	$12.679+
Carpenter work	"	33 109	226.17	6.831+
Filling rock	Cubic yards.	1 105	263.38	0.238+
Total			$909.35	

Lock and Abutment No. 3.

(Lock masonry, 10 885 cu. yds.; abutment masonry, 530 cu. yds.)

Stone quarried	Cubic yards.	11 415	$18 923.38	$1.657+
Stone cut	"	3 997	24 057.88	6.018+
Masonry laid, including cement	"	11 415	20 691.09	1.812+
Earth excavation	"	3 520	910.35	0.257+
Rock excavation	"	2 500	2 501.68	1.000+
Earth filling	"	7 496	2 156.41	0.287+
Paving, 12 ins. thick	Square yards.	7 036	966.43	0.137+
Gates and valves			9 919.30	
Handling and hauling			8 510.01	
Boats and buildings			3 445.21	
Track and roads			2 022.80	
Tools and plant			17 852.08	
Engineering and superintendence			18 892.26	
Incidentals			5 712.64	
Total			$131 561.47	

TABLE No. 4—(*Concluded*).

Dam No. 3.

(Dam 15 ft. high, 650 ft. long, and 26 ft. width of base.)

Item.	Measure.	Quantity.	Cost.	Rate, per unit.
Lumber and iron	Feet, B. M.	98 759	$1 274.55	$13.598+
Carpenter work	"	98 759	689.77	7.356+
Stone quarried	Cubic yards.	6 180	4 158.50	0.677+
Stone, rough-dressed	"	898	1 403.10	1.171+
Masonry laid, dry rubble	"	6 180	1 916.10	0.312+
Filling above dam	"	1 444	868.85	0.601+
Cement			185.00	
Handling and hauling			1 168.34	
Track and roads			635.48	
Tools and plant			2 668.77	
Engineering and superintendence			1 278.22	
Incidentals			145.15	
Total			$16 336.83	

Guard Crib No. 3.

(Guard crib 28 ft. 8 ins. high, 90 ft. long, and 11 ft. 6 ins. wide.)

Item.	Measure.	Quantity.	Cost.	Rate, per unit.
Lumber and iron	Feet, B. M.	33 109	$468.97	$14.164+
Carpenter work	"	33 109	417.95	12.623+
Filling rock	Cubic yards.	1 090	503.58	0.462+
Total			$1 390.50	

SUMMARY.

Cost of Lock and Dam No. 1	$233 234.50
Cost of Lock and Dam No. 2	158 692.27
Cost of Lock and Dam No. 3	149 288.80
Grand total	$541 215.57

The unit cost of Lock and Dam No. 3 was considerably below that of Nos. 1 and 2, due to favorable conditions and the rapid prosecution of the work. The masonry was begun on June 15th, 1893, and the lock walls were finished on November 8th, 1893. The entire masonry of the lock was completed, ready for the gates and valves, on December 26th, 1893.

Analyzing the cost of Lock and Abutment No. 3 gives the percentages shown in Table No. 5.

TABLE No. 5.

Items.	Cost.	Percentage.
Earth excavation	$910.35	0.7
Paving	966.43	0.7
Track and roads	2 022.80	1.5
Earth filling	2 156.41	1.6
Rock excavation	2 501.68	1.9
Boats and buildings	3 445.21	2.6
Incidentals	5 712.64	4.4
Handling and hauling	8 510.01	6.5
Gates and valves	9 919.30	7.4
Engineering and superintendence	13 892.26	10.6
Tools and plant	17 852.08	13.6
Quarrying	18 923.33	14.4
Cement and laying stone	20 691.09	15.8
Stone cutting	24 057.88	18.3
Totals	$131 561.47	100

The following items do not properly enter into the cost of the masonry:

Earth excavation	$910.35
Rock excavation	2 501.68
Earth filling	2 156.41
Paving	966.43
Gates and valves	9 919.30
Lock tender's house	1 705.76
	$18 159.93

This gives a total cost of $113 401.54 for 11 415 cu. yds. of all classes of masonry, or $9.934 + per cubic yard.

Analyzing the cost of Dam No. 3 gives the percentages shown in Table No. 6.

TABLE No. 6.

Items.	Cost.	Percentage.
Cement	$135.00	0.8
Incidentals	145.15	0.9
Track and roads	635.48	3.9
Carpenter work	689.77	4.2
Filling above dam	868.85	5.3
Handling and hauling	1 168.34	7.2
Lumber and iron	1 274.55	7.8
Engineering and superintendence	1 278.22	7.9
Dressing stone	1 408.10	8.6
Laying stone	1 916.10	11.7
Tools and plant	2 668.77	16.3
Quarrying	4 153.50	25.4
Totals	$16 336.83	100

TABLE No. 7.

Items.	Measure.	Quantity.	No. 1.		No. 2.		No. 3.		No. 4.		No. 5.	
			Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount
Quoins	Cubic yards.	80	$22.00	$1 760.00	$25.00	$2 000.00	$22.00	$1 760.00	$22.00	$1 760.00	$25.00	$2 000.00
Coping	"	300	18.00	5 400.00	20.00	6 000.00	18.80	5 640.00	20.00	6 000.00	18.00	5 400.00
Pointed-face masonry	"	2 240	12.00	26 880.00	19.00	42 560.00	13.50	30 240.00	15.00	33 600.00	15.50	34 720.00
Rock-face masonry	"	1 560	10.00	15 600.00	18.00	28 080.00	12.20	19 032.00	14.00	21 840.00	14.00	21 840.00
Rubble masonry	"	10 940	7.00	76 580.00	9.00	98 460.00	7.40	80 956.00	10.00	109 400.00	7.50	82 050.00
Dry rubble masonry	"	1 900	6.00	11 400.00	8.00	15 200.00	5.50	10 450.00	8.00	15 200.00	5.75	10 925.00
Excavation	"	10 000	2.00	20 000.00	1.00	10 000.00	0.30	3 000.00	0.40	4 000.00	0.50	5 000.00
Rock excavation	"	1 300	4.00	5 200.00	2.00	2 600.00	1.00	1 300.00	1.50	1 950.00	2.00	2 600.00
Embankment	"	5 000	0.50	2 500.00	0.75	3 750.00	0.30	1 500.00	0.30	1 500.00	0.50	2 500.00
Stone filling	"	2 000	1.25	2 500.00	1.25	2 500.00	1.25	2 500.00	1.25	2 500.00	1.00	2 000.00
Paving	"	1 200	2.50	3 000.00	2.25	2 700.00	1.50	1 800.00	4.00	4 800.00	2.50	3 000.00
Rip-rap (hand-placed)	"	1 500	2.00	3 000.00	1.75	2 625.00	1.25	1 875.00	1.25	1 875.00	2.00	3 000.00
Puddling	"	50	1.00	50.00	2.00	100.00	0.50	25.00	2.00	100.00	2.00	100.00
Bolt holes in masonry	Linear feet.	600	0.25	150.00	0.50	300.00	0.15	90.00	0.30	180.00	0.20	120.00
Miter sills	Feet, B. M.	3 600	50.00	180.00	65.00	234.00	25.00	90.00	60.00	216.00	35.00	126.00
Framed timber	"	80 000	30.00	2 400.00	45.00	3 600.00	23.00	1 840.00	40.00	3 200.00	20.00	1 600.00
Sheathing	"	10 000	20.00	200.00	20.00	200.00	25.00	250.00	25.00	250.00	15.00	150.00
Grubbing and clearing	Complete.	....	....	2 400.00	....	300.00	....	1 000.00	....	50.00	....	200.00
Total	....	....	....	$179 200.00	....	$221 209.00	....	$163 848.00	....	$208 421.00	....	$177 331.00

The following items do not properly enter into the cost of the dam masonry:

Lumber and iron	$1 274.55
Carpenter work	689.77
Filling above dam	868.85
Cement	135.00
	$2 968.17

This gives a total cost of $13 368.66 for 6 130 cu. yds. of dry rubble dam masonry, or $2.180 + per cubic yard.

The bids received for Lock and Dam No. 4 are given in Table No. 7.

The work was let to the lowest bidders, at the prices given in bid No. 3.

The latest estimate of the total cost of this lock and dam is $204 500, itemized as follows:

Contract with lowest bidders	$166 260
Gates, valves and irons	12 400
Buildings	4 400
Engineering and incidentals	21 440
Total	$204 500

No detailed estimates of the cost of Locks and Dams Nos. 5 to 11, inclusive, have yet been made.

Commercial Importance.

The modern tendency in the United States seems to be for railroad transportation to supersede other forms of inland transportation. As a rule, the traffic on our rivers and canals is decreasing or at a standstill where well-managed railroads have come in competition, and the railroad traffic is steadily increasing. Also, the general tendency of railroad rates has been downward for many years, and the end is not yet.

There are several reasons for these conditions. Our rivers and canals, the vessels plying upon them, and the owners of these vessels, have, in many cases, not kept pace with modern improvements. They

FIG. 1.—BLACK WARRIOR RIVER: SITE OF LOCK No. 4, LOOKING DOWN STREAM.

FIG. 2.—BLACK WARRIOR RIVER; LOCK AND DAM No. 1, LOOKING UP STREAM.

are still trying to do business as they did fifty years ago. Our railroads are about the most progressive institutions we have, and they have in their employ much of the very best talent in the country. They are generally up to date, and aggressively fight water competition, at a loss, if necessary, and make it up elsewhere.

Much of our water transportation is stopped by ice for 4 or 5 months annually, while the railroads offer much quicker transportation regularly throughout the year and have much better facilities for distributing freight to customers at terminals.

There are a few exceptions in which it seems almost impossible that railroads can ever compete with water transportation. Perhaps the most notable case is the coal traffic in barges from Pittsburg to New Orleans, a distance of 2 000 miles by river. Coal is said to be transported over this route at an actual cost of 50 cents per ton, or $\frac{1}{4}$ mill per ton-mile. The low cost of this traffic is due to good business management and the enormous quantities transported; 50 000 tons and more are frequently handled in a single tow from Louisville down. Probably no railroad would attempt to transport coal from Pittsburg to New Orleans for less than $3 per ton.

The Black Warrior River and its tributaries, the Mulberry and Locust Forks, split in twain the great Warrior Coal Basin, covering an area of some 3 000 sq. miles, and containing by far the finest and greatest deposits of coal south of West Virginia. It is only 400 miles by river from the heart of this coal basin to tide water at Mobile. The best and most extensive bodies of iron ore in Alabama, also the whole Birmingham District, with its wonderful mineral developments, lie within 12 to 30 miles by rail east of these streams. The lock system, when completed, will furnish water transportation throughout the year, for ice is practically unknown in this climate.

It is believed that mines along the river can place an excellent quality of steam coal, f. o. b. barge, at a cost of about 60 cents per short ton, and that the actual cost of transportation, when the lock system is completed, should not exceed 20 cents per short ton, or $\frac{1}{2}$ mill per ton-mile, a rate with which it is probable that railroad transportation can never compete. If these conditions should be realized, not only coal, but pig iron, steel and other mineral products of the Birmingham District can be placed in Mobile more cheaply than similar products can be placed in any other port in the world. This should

result in an enormous export trade from Mobile being rapidly built up, extending not only to the West Indies, Central and South America, but to the ports of all nations.

It is realized that the exact cost of barging coal through this lock system will never be known until it is done on a large scale, and then will vary from year to year with the cost of labor, materials and incidentals; but there is no doubt that the cost will be much less than the present railroad rate of $1.10 per ton. Besides, the improved river will open a large area of coal lands, at present without railroad facilities and utterly inaccessible. Even on the supposition that the railroads will build into this territory and handle the traffic, with an improved river ready to compete with them at all times, they would have to do it at a much lower rate than $1.10 per ton, and the public would save the difference. In fact, one of the strongest arguments in favor of the improvement of rivers and canals by the general government is that they serve to regulate and control railroad rates more effectively than legislation ever can. Able railroad attorneys can generally find some means of evading inimical regulations framed by legislative bodies. Well-managed railroads will probably always find some way of pooling interests when it is greatly to their advantage to do so. But it is a difficult matter to pool with a public waterway, operated and maintained by the general government without tolls, because any town or individual with a few thousand dollars can build an independent boat and "break the combination."

For these reasons, the writer firmly believes that the improvement of these rivers is *pro bono publico*, and therefore worthy of being done by the general government.

Vol. XXVIII. APRIL, 1902. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE BOHIO DAM,

Discussion.*

By Messrs. Frederic P. Stearns, Boyd Ehle, Edward Wegmann and Philipp Forchheimer.

Frederic P. Stearns, M. Am. Soc. C. E.—Mr. Morison, in his interesting comparison of proposed designs for the Bohio Dam, has called attention to the resemblance between the design prepared by him and the North Dike of the Wachusett Reservoir; and the writer, thinking that it might be of interest to the Society to have at this time some further information with regard to this structure which is now being built, has prepared the following description of its design and construction. Mr. Stearns.

The preliminary designs of the dike were made by the speaker in 1894, in connection with the preliminary investigations for the Metropolitan Water Supply made by the Massachusetts State Board of Health. The design is an unusual one, and was the result of unusual conditions.

The Nashua River, at the site of the main dam, flows through a narrow gorge between rocky hills covered with a comparatively thin layer of drift material, and these hills rise far above the proposed water level of the reservoir. Between the hill on the north, however, and another hill nearly two miles to the west, there is a sandy plain having a general level about 15 ft. below the water level in the reservoir. In some portions of the plain small rocky hills or ridges rise

*Discussion continued from March, 1902, *Proceedings*. See January, 1902, *Proceedings*, for paper on this subject by George S. Morison, M. Am. Soc. C. E.

Mr. Stearns. above its surface, in other portions of the plain, there are depressions and gullies.

North of Sandy Pond, which lies in a very deep depression, there is a deep cut through the plain, through which a small stream from this pond formerly flowed, but the building of a mill dam on a stream north of the plain backed the water up into Sandy Pond, and, before the construction of the dike, the water stood in the cut to a depth of from 5 to 12 ft., for a width of about 300 ft. The mill pond formed by the dam, including the arm connecting it with Sandy Pond, was known as Coachlace Pond. The bottom of this pond, at the point where the dike crosses it, is 65 ft. below the proposed water level. Upon making borings, it was found that the rock was far below the surface of the plain, in one place as much as 286 ft., so that it would be impracticable to reach it with any core-wall.

The geological condition of the drift material over the rock, however, was much more satisfactory, as it was found quite generally that the material above the rock, with the exception of the upper layers, was a very fine and nearly impervious sand.

It had been decided, upon sanitary grounds, to strip the surface soil from the whole of the 6½ sq. miles comprised within the limits of the reservoir. The great depth of the reservoir, and the conformation of the sides, made it nearly as cheap to deposit this material at the site of the dike as elsewhere. The abundance of material available at a nominal cost, the fact that less water would percolate through a dike of great thickness than through a thin one, and the desire to provide absolute safety where such an enormous amount of water was to be stored, led to the adoption of a design which is characterized by very unusual dimensions.

Dimensions of the Dike.—The dike covers an area of 143 acres, and will contain 5 500 000 cu. yds. of material. It is 2 miles long on the water side at full-reservoir level, 65 ft. high at the deepest place, up to this level, and has a maximum width of base of 1 930 ft.

In order to prevent the percolation of water through the upper layers of the plain, which, in most cases, consisted of coarse sand or fine gravel, an excavation known as the cut-off trench was made. This has a total length of 9 556 ft., a bottom width of 30 ft., and a maximum depth of 60 ft., and extends longitudinally under the crest of the dike. For 3 124 ft. the trench was excavated to the solid rock, and for the remaining 6 432 ft. into the fine sand.

Wherever the borings indicated that the material at a level below the cut-off trench was somewhat pervious, or where they showed streaks of the coarser sand, sheet-piling was driven in the bottom of the cut-off trench. This sheeting was driven for a total length of trench of 5 245 ft., leaving 1 187 ft. of trench without sheeting.

The portion of the dike easterly from a central rocky ridge, known

Mr. Stearns.

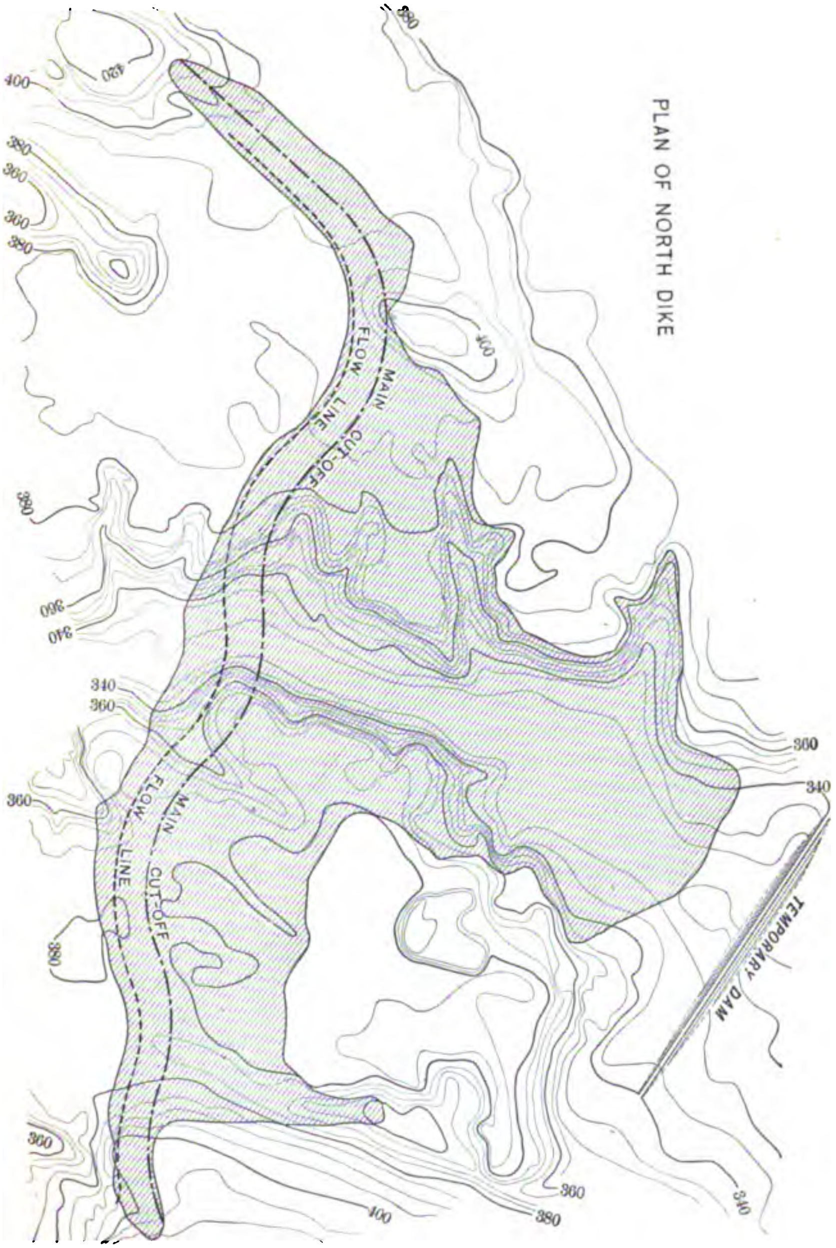


Fig. 10.

Mr. Stearns. as the Easterly Portion of the dike, presents the most interesting problems, and is shown in plan by Fig. 10, and in cross-section by Fig. 11. The characteristic features of the design are best shown on the cross-sections, one of them through the highest part of the dike and the others through the higher ground where the water will have a depth against the dike of only 13 and 20 ft., respectively, but where the pervious character of the upper layers made it necessary to excavate a deep cut-off trench and fill it with impervious material.

The top of the dike is to be 17 ft. or more above the full-reservoir level, with a view to having it not less than 15 ft. above this level in the future after the material has settled.

The distance through the dike at the full-reservoir level is 189 ft. The down-stream slope, as a rule, is only 3%, but there are exceptions to this rule, and in some places the slope is as high as 6 per cent.

The water face of the dam has a slope of 2 horizontal to 1 vertical, both above and below a berm 15 ft. in width and 13 ft. below the full-reservoir level.

Materials Used in the Dike.—As already indicated, soil stripped from the reservoir is used for by far the greater part of the embankment of the dike. This was found, by experiments which will be described subsequently, to be practically impervious, and, except for a tendency to settle under pressure, to have a high degree of stability, and was, therefore, used for filling the cut-off trench as well as other parts of the embankment.

The water face of the embankment is to be protected above the berm with a layer of coarse gravel, 7 ft. in thickness, resting on an embankment of either sand or gravel and covered with a well-laid paving, 3 ft. in thickness, of large stones embedded in and chinked with broken stone. The paving will extend from 8 ft. above the water level down to the berm, but will diminish in thickness toward its upper and lower ends. Below the berm, light rip-rap may be used in exposed places, but, as a rule, a layer of coarse gravel will be sufficient.

It seemed advisable to give the cut-off trench a considerable width, and it was found to be both better and cheaper to excavate a trench with slopes rather than with vertical sides protected by sheeting. The open excavation, besides being cheaper to make, facilitated the work of driving sheet-piling. It furnished most of the material for the sand and gravel embankment at the water face of the dam, and its form is much more satisfactory than with vertical sides, where the trench is to be filled with a material which will compress as it is loaded more and more by the filling of material above it.

A secondary cut-off, of somewhat smaller dimensions, was provided for a part of the length of the dike, in the position shown on the cross-sections, as an additional precaution which could be

Mr. Stearns.

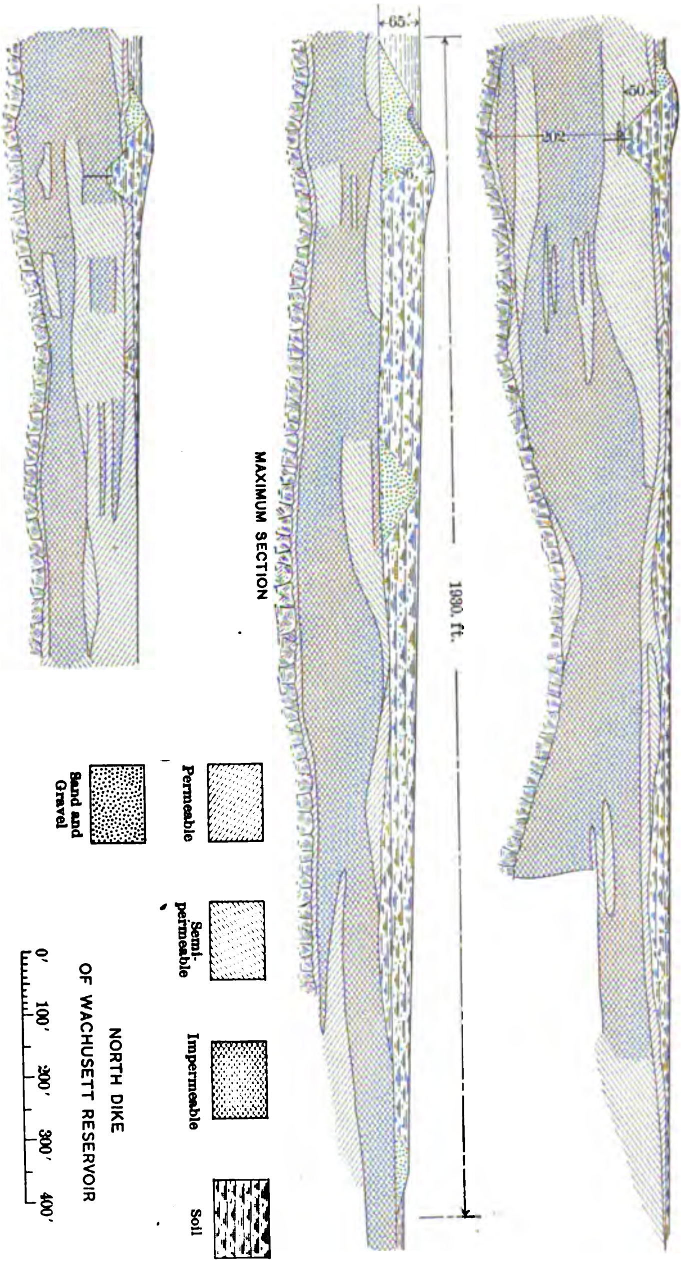


FIG. 11.

Mr. Stearns. provided at a small expense. A secondary embankment of sand and gravel was also added, to meet a suggestion that the soil might lack stability.

The sheet-piling in the bottom of the cut-off trench was an important part of the work, which was accomplished in a very satisfactory manner. The borings showed the presence of fine sands, not wholly impervious, to a depth of 50 ft., in many places, below the bottom of the trench, which made it desirable to use unusually long sheeting if a method of driving could be devised which could give satisfactory results. The entire absence of stones or other coarse material indicated that good results might be obtained with a water-jet.

As it was impracticable to obtain single planks for sheeting of such great length, it was decided, where the lengths exceeded 30 ft., to make the sheeting 6 ins. in thickness and to build it of 2-in. planks in substantially the same manner as the Wakefield triple-lap sheet-piling. Where the length was less than 30 ft., 4-in. grooved spruce sheeting was used. The 2-in. planks were of standard widths, planed to an even thickness and nailed together, except at the lower end, where they were bolted to resist water pressure. The piles were beveled at the bottom for a part of their width, so that they would hug the pile against which they were driven.

Spruce lumber, costing about $18 per 1 000 ft., B. M., was used for all except a short length at the bottom of the pile, where oak was substituted.

The piles were made of varying widths, generally between 16 ins. and 2 ft., and they were quite commonly from 45 to 50 ft. in length. The longest pile used was 67 ft., and as they were left with their tops 5 ft. above the bottom of the trench in order to make a suitable connection with the soil filling, the greatest depth that a pile was driven into the ground was 62 ft.

For driving the long piles, a pile-driver, 50 ft. high under the hammer, was used, and a water-jet was used in all cases. A large steam pump was installed at the bottom of the trench, and a 6-in. wrought-iron pipe extended nearly to the pile-driver. From this the water was conveyed to the pile by a 3½ or 2½-in. hose, or by a combination of the two, fastened by a detachable coupling to an opening which extended from the side of the pile, near its bottom, to a nozzle at the bottom of the pile. Various kinds of nozzles were used, to meet different circumstances. All of them furnished a heavy stream pointing directly down, and in general there was a stream spurting back toward the pile already driven, to wash away all sand from between the two piles. The large quantity of water used came to the surface around the pile and also around the hose, keeping them free from pressure. The hammer of the pile-driver was used merely to overcome the friction of the pile against the wedges and

the pile previously driven, and to overcome its buoyancy after the pile Mr. Stearns. was driven to a considerable depth into the ground. When the pile had been driven to the full depth, a key, fastened to a small wire rope, was pulled, releasing the hose, which could then be drawn to the surface.

It had been thought, before beginning the work, that it might be desirable to drive two rows of sheeting, but the character of the work done was so satisfactory that it was concluded that one row would be sufficient. The largest number of piles driven at one place in any one day was 28. These piles were 20¼ ins. wide and between 45 and 46 ft. in length. They were driven into the ground from 40 to 41 ft.

The method of constructing and driving the sheet-piling was devised by, and the work executed under the direction of, Hiram A. Miller, M. Am. Soc. C. E., Engineer of the Reservoir Department.

Where the trench was excavated to the rock, the surface of the rock was carefully washed off with a hose, using water under a considerable pressure. All seams were carefully cleaned out and, if small, filled with Portland cement mortar, or if large, with bricks laid in the mortar. Brick cut-off walls were built where needed, and the entire rock surface was covered with two coats of grout put on with whitewash brushes. It was the purpose, in all this treatment of the rock, to prevent any possibility of contact between a concentrated stream, which might possibly follow a seam or narrow channel in the rock, and the soil resting on the rock. The area of the rock surface treated in this way was 77 250 sq. ft.

Plates XX to XXII are views of the cut-off trench and sheet-piling in various stages.

Fig. 1, Plate XX, and Fig. 1, Plate XXI, are views of the cut-off trench where sheet-piling is being driven, Fig. 1, Plate XXI, showing the 6-in. pipe leading from the pump nearly to the pile-driver, and Fig. 1, Plate XX, showing on the left the building in which the piles were built, and the means used for sliding them down to the bottom of the trench.

Fig. 2, Plate XX, shows the interior of the building where the piles were built.

Fig. 2, Plate XXI, shows the lower portion of a pile just before connecting the hose.

Fig. 1, Plate XXII, shows the method of treating the ledge at the bottom of the cut-off trench.

Fig. 2, Plate XXII, shows a portion of the cut-off trench nearly filled with soil rolled in 6-in. layers.

At the extreme down-stream toe of the dam, an embankment of very coarse gravel was formed. Its maximum section is 19 ft. high and 115 ft. wide at the base. This embankment is for the purpose of

Mr. Stearns. permitting any water which may find its way through the dike to escape without the sloughing of the material. If the quantity filtering should prove to be large, there is a coarse gravel stratum below the surface which could be tapped by means of driven wells to furnish an escape for water filtering through that stratum, but it is not anticipated that these wells will be needed.

Cost of the Dike.—The amount expended on the dike up to the present time is about $500 000, and about two-thirds of the work has been completed.

In looking at the cross-sections, one can hardly realize the relative cost of the different materials. The quantities and costs of the completed dike will be approximately as follows:

Soil	5 250 000	cu. yds.,	at $0.05	$262 500
Cut-off trench	542 000	"	" 0.20	108 400
Borrowed earth and gravel	200 000	"	" 0.20	40 000
Slope-paving	50 000	"	" 2.20	110 000
Sheet-piling, pumping, consolidating soil with water, and other day's labor work				117 000
				$637 900
Engineering and preliminary investigations				120 000
				$757 900

The cost of the soil filling cannot, of course, be very definitely determined, as it is an estimated part of the cost of stripping and disposing of the soil from the reservoir, of which the total cost is from 20 to 39 cents per cubic yard. Of the total cost of construction, exclusive of engineering and preliminary investigations, amounting to $637 900, only about two-fifths is chargeable to the great mass of soil of which the dike is composed, and only one-sixth to the cut-off trench, which is of such unusually large dimensions. On the other hand, the slope-paving and sheet-piling, which occupy very little space upon the cross-sections, together represent nearly one-third of the total cost. The cost per linear foot of dike, including the engineering and preliminary investigations, will be about $75.

The Bohio Dam, as designed by Mr. Morison, has two-thirds the bulk of the North Dike, and his estimate of cost, exclusive of protective works, engineering and contingencies, is one-half greater than the cost of the North Dike.

Investigations on which the Design was Based.—In making the original design of the dike, the writer was much indebted, for information with regard to the filtration of water through fine materials, to the investigations of Allen Hazen, M. Am. Soc. C. E., upon the physical properties of sands and gravels.* As indicated by Mr. Morison, Mr. Hazen

* Report of Massachusetts State Board of Health for 1892, page 541.

FIG. 1.—NORTH DIKE: CUT-OFF TRENCH AND PLANT FOR DRIVING 6-INCH SHEETING.

FIG. 2.—NORTH DIKE: BUILDING 6-INCH SHEETING IN SHOP.

determined the laws of the flow of water through sands and gravels with such accuracy that he was able to make a formula to express the results. By the application of this formula, it was evident that the very fine sands found at a considerable depth below the surface would not permit enough water to pass through them, if a dike of great width were constructed, to cause a serious loss of water, and it was also found that the soil which contains not only the fine particles of organic matter but also a very considerable amount of finely comminuted particles, which the geologist has termed "rock flour," would be sufficiently impermeable to be used as a substitute for a clay puddle. The final design, however, was not adopted until after a most extensive series of borings had been made to determine the nature of the material at all depths in all parts of the plain, and an independent series of investigations had also been made with the materials to be found at and near the site of the dike, to determine whether they would be suitable for use. Mr. Stearns.

Borings.—The plain at the site of the dike was so wide that it permitted a large range in the choice of locations, so far as could be judged from surface indications, and it was necessary, therefore, to locate the dike by means of borings.

Owing to the great length and breadth of the territory to be explored and the great depth to the rock, this investigation was a most tedious and expensive one.

Borings were begun with three gangs on April 1st, 1896; three more gangs were added on August 15th of the same year, and the work was then continued without interruption, nearly all of the time with six gangs, until December 13th, 1897. A few additional borings were made in 1898. In all, 1 131 borings were made, having an aggregate depth of 93 553 ft., equal to about 17¾ miles. The average depth was 83 ft., and the maximum depth 286 ft.

The borings were the ordinary wash-drill borings, made by driving a 2½-in. pipe into the ground and washing the material encountered to the top of the pipe by a stream of water forced into the bottom of this pipe through a 1-in. wash pipe armed with a drill at its lower end.

In many instances the outer pipe was driven only through the layers of coarser material, and the 1-in. pipe was forced down into the fine sand, in which a hole could be maintained without a casing. Special methods were used to obtain trustworthy samples of the materials encountered.

Professor W. O. Crosby, Geologist of the Massachusetts Institute of Technology, co-operated with the engineers in regard to the manner of conducting the borings, collecting the samples and interpreting the results.

The samples were classified largely by their appearance, but other features were also considered. When the water coming up the pipe

Mr. Stearns. while making the borings was discolored by clay, the fact was noted in the records, and in such cases a sample would be classified as more nearly impervious than if this note had not been made. The presence of clay in the samples could also be determined by chemical tests, even though a large part of the clay had been washed away and lost. Many of the samples were used for filtration tests, upon a small scale, and these and other tests affected the classification.

Most of the borings at the easterly half of the dike were made where the ground-water level was from 35 to 50 ft. below the surface, and it is an indication of the comparative impermeability of the material that the water discharged by the 1-in. pipe generally came to the surface in a strong stream, notwithstanding there was a head of from 35 to 50 ft. tending to force the water into the ground, and that in many cases the sides of the very deep holes were not cased and the water could percolate into them as freely as the material would permit. There were places, however, where the stream of water flowing through the 1-in. pipe was wholly absorbed by the ground, and such places were noted in the records and served as an indication of the degree of permeability of the strata in which the water filtered away.

Experimental Dike.—For the purpose of making experiments with a dike built of soil, and for other experiments, a building, 70 ft. long and 25 ft. wide, was constructed. Inside this building a water-tight wooden tank, 60 ft. long, 6 ft. wide and 8 ft. high, was built of 2-in. tongued and grooved pine planks, planed on both sides. Within this

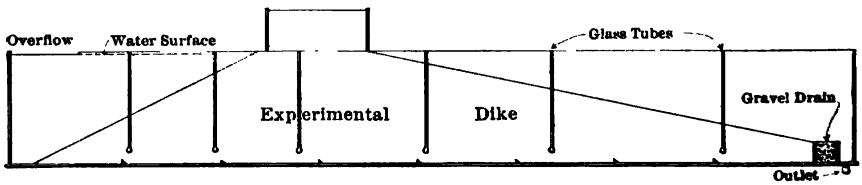


FIG. 12.

tank a dike of soil was constructed, as shown in Fig. 12, 8 ft. high, 7 ft. wide on top and with a slope of 2 horizontal to 1 vertical on the up-stream side and 4 horizontal to 1 vertical on the down-stream side, except at the extreme lower end of the slope on the down-stream side, where there was a box, 18 ins. high, filled with gravel, and having perforated sides, so as to allow the water to filter out at the toe of the slope without carrying the soil with it. Immediately over the top of the dike, for a width of 7 ft., there was placed 3 ft. of soil, so as to slightly consolidate the top of the dike and permit the water to be filled up level with it without overflowing.

After the dike had been formed, the upper end of the tank was filled with water to a depth of nearly 8 ft. In order to determine the

FIG. 1.—NORTH DIKE: MAIN CUT-OFF TRENCH

FIG. 2.—CONNECTION OF HOSE WITH PILE.

pressure in different parts of the dike, horizontal pipes were laid across the tank through the soil, near its bottom, at intervals of from 6 to 12 ft. These horizontal pipes were perforated and covered with wire gauze, and at the end of each there was a vertical glass tube. As soon as the soil surrounding the pipes became saturated and under pressure, the amount of pressure would be shown by the height of the water in the glass tubes. Mr. Stearns.

Experiments were made on dikes with the soil deposited in different ways:

1. When shoveled loosely into the tank without consolidation of any kind.
2. When deposited by shoveling it into water.

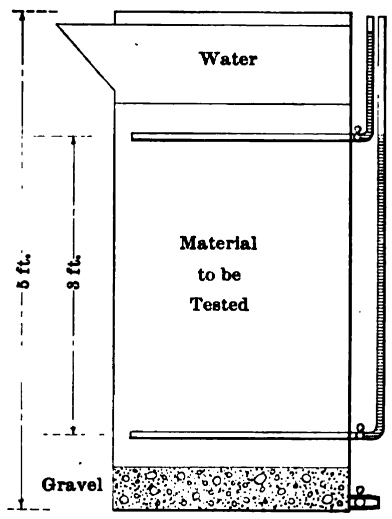
The soil, which had been thrown in loosely, settled as it became saturated by the water and became quite compact. After the pressure had been on for several weeks, the filtration through the dike amounted to only about 1 gall. in 22 minutes. It is interesting to note that it was five days after the water pressure was put on the dike, before any water appeared in the sixth gauge pipe near the lower end of the dike.

In the second experiment the filtration amounted to 1 gall. in 34 minutes.

In a third experiment, made under nearly the same conditions as the second, the rate of filtration was 1 gall. in 35 minutes.

In addition to the filtration test, the experiments showed that a light section of dike, composed of soil not rammed, would withstand a head of 8 ft. of water without failure.

Filtration Experiments.—The experiments above cited show, incidentally, that extremely little water will filter through soil, even when it is not compacted, but a better test, particularly of the relative filtering capacity of soils and sands, can be obtained by filtering through cylinders of known area.



CAN FOR DETERMINING
FRICTIONAL RESISTANCE.

FIG. 13.

For this purpose, five galvanized-iron cylinders, having tight bottoms, were provided (see Fig. 13), each 2 ft. 4½ ins. in diameter and 5 ft. high. The horizontal area, consequently, was 0.0001 acre. In the bottom of each cylinder there was a small wooden drain, in the form of a cross, leading to a faucet on one side of the

Mr. Stearns. cylinder. Over the drain were placed stones about 2 ins. in diameter and on them smaller stones, diminishing in size, were added, until at the top of a 5-in. layer the material was either a fine gravel or coarse sand. Upon this layer, which would remove water freely, was placed the filtering material to be tested, to a depth of 3 ft. 8 ins. Within this filtering material, 4 ins. above its bottom and 4 ins. below its surface, were placed horizontal, perforated, brass pipes covered with wire gauze, and extending through the sides of the cylinder. These were connected with ½-in. vertical glass tubes. The water to be filtered was applied in a steady stream at the top of the filtering material, so that it stood about 10 ins. deep, and was maintained at a constant level by admitting more than would filter, allowing the surplus to pass over an overflow. When the experiment was in progress the water appeared in the glass tubes, and rose in each of them to a height due to the pressure of the water in the filtering material in immediate contact with the corresponding perforated brass pipe. The difference in the height of water in the glass tubes showed the amount of head lost by filtering the amount of water passing through the material. When it was desired to filter with a smaller loss of head than that due to a free outlet at the bottom of the tank, a stop-cock was partly closed, so, that the water in the glass tube connected with the lower brass pipe would rise.

Experiments were made with gravel, sand of all grades, and soil from various locations, such as upland and intervale.

The experiments confirmed those of Mr. Hazen, by showing that the loss of head was directly proportional to the quantity of water filtered, and substantially confirmed his conclusion that the quantity filtered will vary as the square of the diameter of the smaller grains of the filtering material. The smaller grains referred to are those which separate the finer 10% from the coarser 90%, and are the grains which, according to Mr. Hazen's experiments, determine the "effective size" of the material for filtration.

To give all the experiments in detail, with the results of the mechanical analyses of the materials used, would require more space than it seems desirable to use in this discussion. The experiments with coarse and fine gravel are, therefore, omitted, and those with sand are grouped together in four grades, in Table No. 6.

TABLE No. 6.—AMOUNTS OF FILTRATION, IN GALLONS PER DAY, THROUGH AN AREA OF 10 000 SQ. FT. OF DIFFERENT MATERIALS, WITH A LOSS OF HEAD OF 1 FT. IN 10.

Coarse sand, average of three experiments	2 200 000
Medium sand, average of six experiments	400 000
Fine sand, average of two experiments	90 000
Very fine sand, average of two experiments	7 200
Soil, average of ten experiments	510

FIG. 1.—NORTH DIKE: CUT-OFF TRENCH, SHOWING TREATMENT OF LEDGE.

FIG. 2.—NORTH DIKE: FILLING CUT-OFF TRENCH WITH SOIL.

In order to express the results with a convenient unit of area, 10 000 sq. ft. has been adopted for the filtering area, and a loss of head or slope of 1 ft. in 10. Mr. Stearns.

It is of interest to note the very great difference between the amount of filtration through the coarse sand and the very fine sand, and also to note how much less water filters through the soil than through the finest sand. The ratio of filtration through the various materials, as compared with the filtration through soil, is more clearly shown if each of the figures is divided by 510, so that the amount of filtration through soil will be the unit, as follows:

Coarse sand	4 353
Medium sand	784
Fine sand	176
Very fine sand	14
Soil	1

There was some question, in view of the very small amount of water filtering through the soil, whether there might not have been some accumulation of air in its interstices, which diminished the amount of filtration, and it was therefore decided to experiment on the horizontal filtration of water through soil. For this purpose the large wooden tank used for the experimental dike, for a length of about 50 ft., was filled to the top with soil taken from an upland pasture. In order to retain the 50-ft. section of soil in place, and to allow the ingress and egress of the water without disturbing the soil, screens were placed about 55 ft. apart, and about 2½ ft. of porous sand and gravel were filled in between the screens and the ends of the section of soil. The soil was rammed in 3-in. layers, and special care was taken to prevent any water from following along the sides of the tank. At each end of the tank a space was left unfilled with earth, and one of these spaces was filled with water to a depth of 7.85 ft., while at the other end a free outlet was maintained.

After the experiment had been continued for more than a month the amount of filtration, although somewhat variable, averaged about 1.7 galls. in 24 hours, indicating that the rate of filtration was as low as that obtained by the experiments in the galvanized-iron tanks. The tightness of this soil dam could be better appreciated by seeing it than by a statement of the figures. Although the section of dam was 6 ft. long and very nearly 8 ft. high, the leakage from the outlet amounted to only 32 drops in a minute.

To test the filtration through soil under greater pressure, a 10-in. pipe, to which a cover could be bolted, was used in the place of the galvanized-iron tanks, and the pressure upon soil 8 ft. in thickness was raised as high as 65 lbs. per square inch, equal to a head of 150 ft., and the results were not materially different from those deduced from the experiments in the galvanized-iron tanks.

Mr. Stearns. As the soil to be used in the dike contained from 4 to 8% by weight of organic matter, the question arose as to whether, if this organic matter were to disappear, the soil would not become permeable. To determine this point comparative filtration experiments were made in the 10-in. pipe with soil as it came from the ground, and again after the organic matter had been burned out of it at the mining laboratory of the Massachusetts Institute of Technology.

Experiments were made for eight weeks with the natural soil and for eleven weeks with incinerated soil, with the result that about one-fifth more water filtered through the latter than through the former.

Stability of Soil.—The question having arisen as to whether soil when saturated would not be so mobile that it would not withstand the pressure of water, two experiments of the same kind were made; one with upland and the other with intervale soil. Each gave substantially the same results.

To make the experiments, the soil was filled into the large tank already described and compacted so as to form an embankment 2 ft. wide on top, 6 ft. high and with slopes of 2 horizontal to 1 vertical on both sides, as shown in Fig. 14. The embankment was then saturated by filling the tank on both sides of the embankment with water to a height of 5 ft. above the bottom. The top of the embankment was covered with 4-in. planks each 2 ft. long, and, running lengthwise of the embankment. On these planks was placed a 12 x 14-in. hard pine beam, 6 ft. long, extending across the tank. Two large jack-screws were placed between this beam and another securely fastened above it, and were operated so as to press the planks into the soil. The apparatus did not permit of an exact measurement of the pressure, but it was between 28 and 42 tons applied to 12 sq. ft., making the pressure probably about 3 tons per square foot. The 4-in. planks were pressed down into the soil a little more than 6 ins., but the embankment was so stable that there was only a very slight bulging at the sides a short distance below the water level, showing that there was enough friction between the particles of which the soil was composed to make it stable.

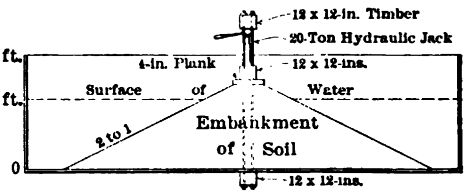


FIG. 14.

This experiment, in addition to showing the stability of the soil, was also interesting as showing the extent to which soil would compress under heavy pressure. Immediately below the planks, where the pressure per square foot was greatest, the soil became hard and compact.

The engineer in charge of the experiments states that his weight would easily push a sharp-pointed steel rod, $\frac{3}{4}$ in. in diameter, down to the bottom of the tank through the part of the embankment which had not been subjected to pressure, and that directly under the planks the soil was so compact that his weight would force it down only from 6 to 8 ins. This result is in line with other experiments subsequently made upon the compression of soil, and with practical experience where large banks of soil which have stood for a considerable time have been re-excavated. The compressed soil needs a pickaxe to loosen it, and is very different from loose soil such as one sees dug from the ground or dumped from a train. Mr. Stearns.

Will Filtration Cause a Fine Material to Penetrate a Coarse One?— The question having been raised as to whether soil filled into a sand and gravel trench might, when the pressure was applied, penetrate the interstices of the sand, it was decided to make the following experiment, notwithstanding the fact that it is well known, from practical experience with water filtration, that fine particles are not carried to any considerable extent into the interstices of the sand. The 10-in. cylinder, already referred to, was filled to within 3 ins. of the top with medium sand and then 3 ins. of soil were put on the top, the end of the cylinder was closed, and water was applied, with a pressure of 65 lbs. per square inch. The water was allowed to filter through the soil and sand for a week, and upon examination at the end of this time there was no indication of any movement of the soil or that any of it had worked into the sand.

Permanence of Soil.—An engineer naturally dislikes to use, in an important and permanent structure, a material which is not permanent, and the question was, therefore, raised as to whether soil which is known to contain a considerable amount of organic matter would be permanent. It was thought best to refer this matter to experts, and Mr. Allen Hazen and Professor W. O. Crosby were requested to report upon it.

They agreed in their separate reports that organic matter would disappear very slowly, indeed, except by oxidation with free oxygen present; that in the portion of the dike which was saturated there would be very little water filtering from the reservoir, and the free oxygen obtained from this source would, therefore, be very small; also, with regard to oxygen contained in the rainwater which fell upon the dike, that it would be removed from the water as it filtered through the upper layers of the soil. Their main conclusion, therefore, was that the process of oxidation below the line of saturation would be extremely slow, requiring many thousands of years for the complete removal of the organic matter, and that the tightness of the dike would not be materially affected by any changes which are likely to occur. There will, no doubt, be some settling of the material of the

Mr. Stearns. dike in the course of years, mostly in the portions above the line of saturation, but, as due allowance has been made in the height of the filling for this settlement, it will do no serious harm. Below the line of saturation, which is the only place where changes in the condition of the soil can do any harm, there is a heavy pressure upon the soil, caused by the weight of the upper layers, and the material is sure to remain compact, even if some of the organic matter should be removed by chemical action. Mr. Hazen, in his report, suggested that this heavy load was likely to push the grains of mineral matter nearer together and to crowd the organic matter into the interstices, so that the disappearance of organic matter from the compressed soil would cause less settlement than from soil that was not compressed.

At the bottom of the deeper portions of the cut-off and of the maximum section of the dike there is a pressure of about 4 tons to the square foot upon the bottom soil, and of nearly a ton per square foot upon the soil at the limit of saturation. Attention has already been called to the experiment which showed that the soil with all organic matter removed was practically water-tight.

Comparison of Dike with Existing Dams.—Fig. 15 shows eight comparisons between the North Dike and existing earth dams. Where the existing dam had less height than the maximum section of the North Dike, the comparison is made with a section of the dike having the same height up to the water level; where the existing dam was higher than the North Dike, the comparison is made with the maximum section of the dike. The black, heavily-shaded portion is in every case the existing dam, while the light shading represents the North Dike. The black central walls shown in connection with several of the existing dams are clay walls, in every case excepting the Sudbury Dam, where the wall is of concrete, plastered on its up-stream face. Similar comparisons were made with many other dams, and they showed similar results, namely, that the dimensions of the North Dike are far in excess of those of any structure of this kind which has been built. The Jeypore Dam has no core-wall, and is composed largely of sand and other light earth, resting upon a foundation of the same general character.

Stability of Dams.—At this time, when not only the great dams of the Isthmian Canal are under consideration, but there is much discussion in the engineering papers with regard to the stability of earth dams, and many accounts of the failure of masonry dams, it seems opportune to discuss briefly the stability of dams in general.

In order that a dam may fail it is obviously necessary that the material of which it is composed must move, either as a whole or in part, under the pressure or the flow of water. If a dam has great bulk and weight and a reasonable degree of stability it cannot fail by sliding on its base or by overturning as a whole, but must fail by some separation of the parts.

Mr. Stearns.

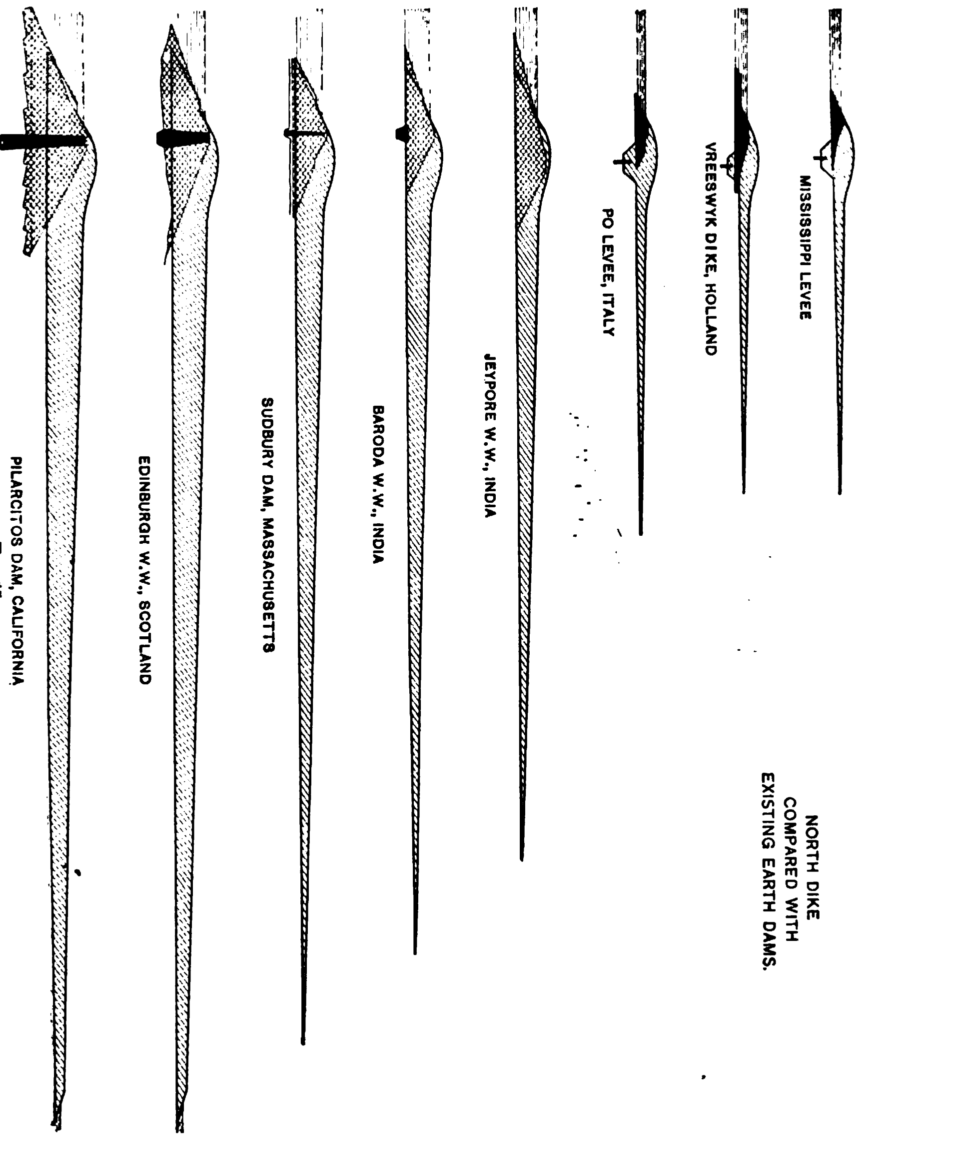


Fig. 15.

Mr. Stearns. In the case of earth dams, failures have generally occurred from the wearing away of the material by a current of water, either flowing over the top of the embankment or through some passageway formed in the dam, in connection with a pipe through it or by some burrowing animal.

Occasionally, an earth dam with steep slopes, or one with flatter slopes in which the material on the down-stream side retains the water, will fail through the sloughing of the down-stream slope, but the speaker does not know of any instance in which the earth confined in or under a dam has been moved by the filtration of water through it.

The tendency among many engineers at the present time seems to be to pay more attention to the materials and method of construction than to bulk. Many masonry dams have been built upon a somewhat theoretical cross-section, without taking into account the upward pressure of water on the base of the dam and the many uncertainties as to what will actually occur when the dam is put under great pressure; as a result, the failures of masonry dams over which large quantities of water flow have been numerous. A comparison of the sections of such structures with the sections of the upper part of masonry dams which rise to a considerable height above the water, like the New Croton Dam and the Wachusett Dam, shows the relatively small weight of these spillway sections, and no amount of good workmanship will compensate for the failure to provide sufficient weight.

The writer has frequently been asked why he did not use Portland cement throughout the whole section of the Wachusett Dam, and his answer has been that, except in the parts of the dam where Portland cement has been used, natural cement will withstand all the pressures that can occur, and that with natural cement the same amount of money will build a dam of so much greater weight as to provide absolute security against sliding or overturning.

In the case of earth dams, the bulk is necessarily large, so that with well-constructed dams there are practically no cases of failure, except where the material has been washed away by a current of water.

In the case of the North Dike, the top being 15 ft. or more above the full-reservoir level and 10 or 12 ft. above any height which is likely to be reached during freshets, it is impossible that any water should ever run over the top. There are no pipes or structures through the dike to form channels through which any current of water could flow to remove the material. The dike is protected against burrowing animals by the paving and broken-stone protection on the water face, extending 8 ft. above and 13 ft. below the reservoir level, but even without this protection an animal would have to burrow 289 ft. to reach a point on the down-stream side of the dike 3 ft. below the water level.

There is another advantage in having a great mass of material Mr. Stearns. above the water line of the reservoir, which is worthy of consideration, viz., that in the event of the brief control by an enemy or a mob it would be impossible to remove enough material to cause the failure of the dam.

The filtration through the dike will be so slow, and will take place where there is such a load upon the material, that there can be no possible movement of the particles on account of this filtration.

The precautions taken at the down-stream toe of the dike are such that the water cannot accumulate and cause it to slough, and even if any trouble of this kind should occur it would take place so far from the principal part of the dike that it could be remedied before any trouble could possibly occur.

In the case of the plan proposed by Mr. Morison for the Bohio Dam, the writer believes that it cannot fail to be safe if the crest is built so high that floods or waves cannot possibly overtop it, and if the dam is properly built. Such a large mass of material, in a dam which is constructed so as to be less pervious near the reservoir than toward the down-stream toe, cannot be pushed or washed away. If a large amount of water should filter through the material under the dam and come out at the lower end, it may cause some movement of material in the vicinity of the toe unless precautions are taken to prevent it. Few engineers who deal with filtration would wish to say that they could not design the down-stream portion of such a dam in a way to permit the water filtering through the dam to come to the surface without carrying earth with it. There are many large natural springs at the base of sand or gravel banks, and large quantities of water filtering into artificial excavations, which furnish examples of water coming to the surface without disturbing the material through which it comes.

While referring to the percolation through such a dam, it may be well to call attention to the comparative sections of permeable material of the Bohio Dam and the North Dike, as illustrated by Mr. Morison in Fig. 8. The area of this material at the North Dike as shown by him is correct, and it is larger than the area given for the Bohio Dam. The degree of fineness of the material, however, is very different. He states that the effective diameters of certain samples from the Bohio Dam average by their squares 1.11 mm. Making allowance for these samples being coarser than the average sample of permeable material and for the fine material lost, he suggests that the average diameter of the material in place may be taken at 0.50 mm. The material classed as "permeable" at the North Dike has an effective diameter of about 0.20 mm., and, since the percolation varies as the square of the diameter, the percolation at the North Dike, with the same loss

Mr Stearns. of head, would be less than one-sixth of the percolation per unit of area at the Bohio Dam.

The design of the North Dike was prepared after consultation with Joseph P. Davis and A. Fteley, Members, Am. Soc. C. E., and Mr. Hiram F. Mills, A. M., C. E., of Lowell, Mass., and the final design received the approval of these engineers. Thomas F. Richardson, M. Am. Soc. C. E., Engineer of the Dam and Aqueduct Department of the Metropolitan Water-Works made most of the preliminary investigations, and Hiram A. Miller, M. Am. Soc. C. E., Engineer of the Reservoir Department, completed the investigations, worked out the details of the design, and has had charge of the execution of the work.

Mr. Ehle. BOYD EHLE, Assoc. M. Am. Soc. C. E.—Mr. Morison has covered the subject so thoroughly on its theoretical side that little can be said in addition. There is one point, not mentioned in the paper, which would be in favor of the construction proposed by the author at Bohio. It is probable that it would be safer in case of earthquake action than a masonry or a core-wall dam. This subject, however, received the careful consideration of the Isthmian Canal Commission, and was passed over as not being a serious danger. It may have been similarly dismissed in this paper. The recent earthquakes on the Isthmus, however, have cracked the masonry and adobe walls, at times, quite seriously, and, in more severe shocks, might be a factor to be reckoned with in canal construction. Their action would have no more effect on the elevated plateau that Mr. Morison proposes than on any other part of the impounding reservoir.

Mr. Stearns has shown an earthen dam, under a head of 70 ft., performing its duty efficiently in spite of the leakage. A similar case, on a somewhat smaller scale, occurred in the writer's early experience, in building an intake dam for a reservoir on a small stream. The channel was closed by a timber weir abutting on a sand and gravel point, in deference to the wishes of the Water Commissioners. Sheet-piling, driven lengthwise of the weir to a practically impermeable stratum, was quite effective, but there was considerable seepage around this and through the gravelly material, which was shown by large springs at the foot of the bank. This occurred under a head of about 12 ft. As there was plenty of water, and the bank held, anxiety was dulled, and the reservoir has served its purpose for a long time.

In the great irrigation reservoirs of India there are earth embankments, miles in extent and greater in height than Mr. Morison proposes. These were built by native carriers with baskets, and compacted by elephants, and they do their duty as surely as the fine masonry dams built by the English engineers. Given sufficient earth, there must be a limit to the size of a great mound which will impound water. This is the situation on the Panama Canal, where there is a quantity

of material greatly in excess of that which Mr. Morison proposes to use, and which must be wasted. If it is once on the cars it can just as well be dumped in the Bohio dam, although there seems to be no doubt in the chain of reasoning that the dimensions proposed will be ample. Mr. Ehle.

In regard to Mr. North's statement that the 90-ft. pressure on this bank of material might produce a movement that would endanger the dam, it would seem that this objection, if probable, would apply with much greater force to a light core-wall dam. Of course, by using pneumatic caissons the dam would not be tight, either at the base or around the sealing caissons. It would seem to be impossible to sink them to the great depths proposed, on a straight line, as drawn on the plan; and if there was a movement, by earthquake or pressure, it would be but an earthen dam, subject to seepage, but of very much less section than Mr. Morison's dam. It is not by any means granted that the core-wall will be troubled by pressure, and, without doubt, the dam, as planned, would be a safe and conservative design, but the earthen dam may perform similar duty and be more economical.

As Mr. Morison has located his dam far enough above the Commission's site, it would seem wise to build it, against all objections. It would be as cheap as any temporary dam, and it seems very probable that it would be as efficient. If any serious doubts as to safety arose, it would be of great service in building the Commission's dam.

A point, foreign to the paper, has been interjected into the discussion, in regard to the probable unhealthfulness in building the dam, on the basis of the statement, that "each tie of the Panama Railway has cost a man's life." To anyone acquainted with the conditions, this is a gross exaggeration. Citizens of the United States, long in the employ of the Panama Railway, seem to have no such knowledge of great mortality, and have no trouble with the climate. Whatever measure of truth there is in this story is due to the entire absence of any sanitary precautions and a proper water-supply system. The water carts in Panama often take their supply from wells that drain the yellow-fever burying grounds. Again, it must be recognized that the Panama Route, almost from the discovery of the Continent, has been a great highway, without a proper quarantine. It is very probable that, if the work is undertaken by the United States Government, the same strict regulations which were enforced at Havana, Santiago and elsewhere in Cuba would be equally efficient at Panama or Nicaragua.

Another point, also brought up, but foreign to the paper, is the question of relative economy of a dam at Bohio and at Conchuda, in Nicaragua. The site of the latter dam is very dissimilar to that at Bohio, being in a rocky gorge without any proper location for a separate spillway, such as the Gigante, so that the dam must act as a weir, and have controlling works on the crest for the regulation of the summit level. It would seem that the Commission's plan is the

Mr. Ehle. correct engineering solution. As has been pointed out, it is the duty of the engineer to adopt the most economical, effective, and safe tool for a certain purpose, not any one or an elaborate one.

It seems probable that the reason earthwork dams have been going out of use, as engineering has become more scientific, is on account of the lack of method in analysis. If this is so, the formulas given by Mr. Morison place this structure on the same plane as the retaining wall and others. Even in bridge and structural iron-work there is a considerable factor of ignorance.

Mr. Wegmann. EDWARD WEGMANN, M. Am. Soc. C. E.—(by letter).—The plan proposed by Mr. Morison for the Bohio Dam is so much more economical than either the plan of the French engineers, or that recommended by the Isthmian Canal Commission, that it certainly deserves very careful consideration.

A dam built in this manner would certainly be water-tight itself, and the only leakage that might occur would be due to percolation through the permeable material below the proposed sheet-piling. Such leakage, if it did not exceed the amount estimated by Mr. Morison, would be of no consequence.

In constructing dams for impounding water for a domestic supply, it is generally necessary to make them so tight that practically no water is lost, except by evaporation. In storing water for irrigation or for supplying a canal, such water-tightness in a dam may not be necessary.

If Mr. Morison's estimate is even approximately correct, the loss of water by percolation under the dam would be relatively unimportant. We may doubt whether Mr. Hazen's formula for the flow of water through a uniform layer of sand is applicable to a mixed layer of sand, gravel, etc., such as probably exists under a part of the proposed Bohio Dam, but, on the other hand, there is no question that there would be a silting up which would steadily diminish the loss by percolation.

Should the loss of water from this cause prove to be much greater than that estimated by Mr. Morison, so as to impair seriously the usefulness of the reservoir, this loss could be diminished very materially by sinking wells, by dredging, or, if necessary, by pneumatic caissons on the down-stream side of the proposed dam, or in the earthen part of the dam, a little up stream from the down-stream rock-fill. If the latter plan should be adopted, the earth filling at the place where the wells or caissons would have to be sunk might be omitted until the remainder of the dam was completed, when experience would show whether the percolation had to be checked. The expensive work of sinking wells or caissons could thus be postponed until it was found to be absolutely necessary.

The water percolating beneath the proposed sheet-piling, which is to extend 50 ft. below tide, would move with a very slow velocity, have

little head, and could certainly be checked at the down-stream side of the dam. Mr. Wegmann

Wells sunk by dredging, as suggested by Mr. Morison, placed as closely together as possible and filled with concrete would probably suffice for this purpose. Grout might be forced between the wells, as low down as a diver could work, to check still more the percolation. If it were deemed necessary, pneumatic caissons could be sunk on the down-stream side of the dam, but even in this case, Mr. Morison's plan would probably be cheaper than that proposed by the Isthmian Canal Commission, as he has adopted a shorter location, needs no concrete core-wall in the dam, and proposes to construct the dam mainly of waste material from excavations made for the canal.

Of course, future borings may show reasons for modifying the opinion expressed herein, but the additional facts that may be ascertained are just as likely to be for as against the plan proposed by Mr. Morison.

Mr. Forchheimer.

PHILIPP FORCHHEIMER* (by letter).—The formula used by the author for the calculation of the seepage is backed not only by Mr. Hazen's experiments but also by those made by Seelheim, Hagen and Kröber. For a temperature of 10° Cent., Mr. Hazen puts $V = 450$ to $1\,200\ d^2 \frac{h}{l}$, d being the effective diameter of the sand. The proportion of the mean diameter of grain, d_m, to the effective diameter, d, varies very much. For $d_m = 1.73$, d_m or $d_m^2 = 3d^2$. Mr. Hazen's formula would show $V \frac{l}{h}$ to lie between 112 and 400 d^2_m, or the relation, $V \frac{l}{h}$: d^2_m, to be between 112 and 400. According to the other experimentists, the corresponding figures are as shown in Table No. 7.

TABLE No. 7.

	Seelheim.		Hagen.	Seelheim.	Kröber.	Seelheim.	Kröber.			
d_m = ...	0.16	0.23	0.28	0.48	0.54	0.68	0.7	0.9	1.35	2.1
$V \frac{l}{h}$: d_m = ...	323	319	310	328	367	324	353	425	314	355

If the sand is but slightly soiled by other substances the velocity diminishes very much. Professor Masoni, for instance, used different

* Professor of Hydraulics at the A. D. K. K. Technischen Hochschule, Gratz, Austria.

Mr. Forchheimer. sands taken from the seaside near Naples, and from Mount Vesuvius. He did not wash his sand as thoroughly as Mr. Hazen, and Table No. 8 shows that most of his velocities were much smaller in comparison.

TABLE No. 8.

Sand.	I.	II.	IIa.	III.	IV.	V.	VI.
Effective diameters, in millimeters..........	0.55	0.45	0.45	0.46	0.40	0.38	0.37
Masoni's speed for head, h, equal to distance, l, in meters per day.................	231	9.2	22	47	40	15	11
Speed, in meters per day, according to Hazen's formula, $V = 1\,000\,d^2 \frac{h}{l}$, h being $= h$....................................	302	202	202	212	160	144	137

If sandy soil contains clay to such an extent that the clay fills up the interstices between the grains of sand entirely, the percolation is so insignificant as to render the compound practically impervious. Seelheim made some accurate experiments on the percolation through sandy clay consisting of pure clay, powdered chalk, quartz sand and water (Al_2O_3, $SiO_2 + 2.3\,H_2O$). According to his formula, as rectified by the writer, the rate of flow, at a temperature of 12° Cent. in meters per day is only

$$V = \frac{1}{1\,000} \times \frac{0.0011 \text{ clay} + 0.0023 \text{ chalk}}{\text{water} + \text{sand} + \text{clay} + \text{chalk}} \times \left(\frac{\text{water}}{\text{clay} + \text{chalk}}\right)^2$$

the words clay, chalk, etc., meaning the volumes of the ingredients mixed.

In Nature, clean sands or gravels are rare, and the permeability of alluvial deposits is therefore mostly a slight one. Public water supplies are generally taken from the most permeable strata that can be got at. The investigations made for water-works are therefore of special interest. Table No. 9 gives the velocities (taken for the entire cross-section of soil) which ground-water of about 10° Cent., or 50° Fahr., acquires at a gradient of $h : l = 90 : 2\,500 = 0.036$, in some of the underground drifts studied for public supply :

TABLE No. 9.

Town.	Lyons.	Strassburg.	B. Gladbach.	Augsburg.	Vienna.	Bukarest.
Speed, in millimeters per second........	0.068	0.179	0.099	0.148	0.034	0.051
Speed, in feet per second...............	0.000224	0.000588	0.000292	0.000485	0.000112	0.000166

At 90° Fahr., speeds are two-thirds higher than they are at 50°; but, even at that high temperature, the speed in none of the quoted grounds would come near to the 0.002 ft. per second taken into account by the author. Besides, it must be noted that some of these grounds contain gravel and pebbles some inches in thickness. It is thus apparent that to use Mr. Hazen's formula, which refers to well-washed sand, means to be on the safe side, as indeed the author wishes to be. Mr. Forchheimer.

But there is one more danger to be feared, and that is the formation of springs. This depends entirely on the uniformity of the Bohio subsoil. Natural passages, in more or less impervious soil, filled with permeable material, are dangerous, if they are much narrower at the outlet than in the interior and near the water-basin. As the same volume of water flows through the whole length of such a drift, its velocity will be inversely proportional to its cross-section. The whole head of water will always be used for the flow, and but little of it will be lost, where the cross-section is considerable and the movement slow. Thus the main part of the head of water will be left for the outlet, causing the water to gush out of it and wash away the sand. It is difficult to say beforehand whether or not the washing out will proceed far enough into the interior to constitute a real danger for the dam. It may be well to add that furrows cut into impervious earth and filled with pervious sand are to be dreaded too, if the water flow enters with a big cross-section and issues with a very reduced one, because the speed increases with the reduction of the cross-section. All these dangers are exceedingly diminished by the great breadth of the proposed embankment. Besides this, there is another well-known fact that gives security, and which has been pointed out by the author. It is, that turbid waters clog their beds with their deposits.

As the writer had to occupy himself with a question of seepage of some importance two years ago, he thinks that some figures about it will be of interest. They refer to the seepage from the river Lech into the discharging canal of the electric works of Gersthofen, in Bavaria. The soil consists of a bed of tertiary *flinz* covered by gravel. The former varies in its character between loam and loamy sand, and, although some water-bearing veins occur, it may be considered as practically water-tight. The gravel is pervious, and the writer—using Fossa-Mancini's trough—found the frictional resistance to be

$$\frac{h}{l} = \frac{1.77}{10^3} V + \frac{3.18}{10^4} V^2$$

V being the velocity, in meters per day. The surface of the *flinz* was slightly inclined and showed some undulations or furrows. When a great part of the excavation was finished, the writer tested his calculations. The strip of land between the river and the excavation was 250 ft. broad. He calculated a seepage of 91.4 cu. ft. per second for a length of 13 500 ft. of the canal, whereas he only measured 46.8 cu. ft.

Mr. Forchheimer. per second. Part of the difference between the results of calculation and measurement was due to the fact, that the gravel had been less closely packed in the trough than it was in its natural state ; but the principal reason was probably the clogging of the river-bed by sediment.

According to the foregoing formula, used for the seepage at Gersthofen, the friction in gravel increases at a higher rate than the speed. This fact agrees with the experiments or calculations of other authors, as Smreker, von Welitschkowsky, Masoni and Hazen. The writer tested the adaptability of formulas having the shape

$$\frac{h}{l} = a\ V + b\ V^2,$$

as well as formulas having the shape

$$\frac{h}{l} = m\ V^n;$$

a, *b*, *m* and *n* being constants. He found the first form to correspond more accurately to the facts in Nature than the second one. The difference between the two formulas, however, proved to be only a slight one as regarded the Gersthofen material, and the writer's researches about it resulted in the figures shown in Table No. 10.

TABLE No. 10.

V. in meters per day	10.7	27.5	52.6	64.7	67.3	90.2	100.3
$\frac{h}{l} = \frac{8.2}{10^4} V + \frac{1.07}{10^5} V^2$	0.010	0.031	0.078	0.107	0.098	0.161	0.190
$\frac{h}{l} = \frac{4.422}{10^4} V\ 1.316$	0.010	0.085	0.081	0.107	0.112	0.167	0.190
$\frac{h}{l}$, measured	0.010	0.080	0.070	0.107	0.110	0.170	0.190

The writer is not aware as to whether any of the subsoil of the Bohio dam contains material of such coarse structure as to be calculated by a formula of the shape

$$\frac{h}{l} = a\ V + b\ V^2,$$

but he would like to call attention to this possibility.

Vol. XXVIII. APRIL, 1902. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE SUPPORTING POWER OF PILES.

Discussion.*

By Messrs. Horace J. Howe and Joseph P. Carlin.

Horace J. Howe, M. Am. Soc. C. E.—Mr. Goodrich has referred to the speaker's paper on piles and pile-driving,† which went into the subject from a historical and experimental standpoint. Mr. Howe.

Since that time few detailed tests have come to the speaker's notice, the most interesting being those at the Annapolis Naval Academy during the construction of the sea-wall, a year or more ago, and partially described by J. P. Carlin,‡ Jun. Am. Soc. C. E., of the contracting firm which did this work. He states that five piles were loaded singly, to the ultimate, and that the results were compared with the Wellington (*Engineering News*) formula, as shown in Table No. 2.

TABLE No. 2.

Pile.	Safe load as per formula.	Actual ultimate load.	Remarks.
1	38 000	75 000	Point in mud and sand.
2	40 000	85 090	" " "
3	32 000	84 000	Point in mud.
4	33 300	38 000	Pile in sand.
5	50 000	110 000	" "

* Continued from February, 1902, *Proceedings*. See December, 1901, *Proceedings*, for paper on this subject by Ernest P. Goodrich, Jun. Am. Soc. C. E.

† *Journal of the Association of Engineering Societies*, April, 1898.

‡ *The Engineering Record*, May 11th, 1901.

Mr. Howe. The third test pile was entirely in mud, and the factor of safety was assumed as one, in designing the sea-wall at that point. It seems, however, that both the formula and the load actually supported gave figures which were too small, and that the wall settled for 100 ft. in length.

Mr. Carlin can doubtless supply further details.

In the paper above referred to, after a somewhat exhaustive review, the speaker called attention to the fact that single test piles, whether separate or taken from a cluster, are inadequate; and that a test is accurately adequate only when it fulfills all of the subsequent designed conditions of loading, and covers a sufficient area and lasts for a sufficient period of time. The failure of this wall is testimony as to the soundness of these conclusions.

Half a century ago, at Fort Delaware, Major Sanders made two sets of experiments on clusters of four piles each, and extended his observations on the same for some years; afterward evolving his well-known formula. Recent reports (1897) as to the masonry indicate no settlement, and the conclusion is that, under exactly those conditions, Sanders' formula is to be considered applicable.

Looked at from the standpoint of his contribution to the subject, it may be that a formula is not such a forlorn hope, after all, as some have been in the habit of thinking; and that in expert hands it may attain positive value.

It is hoped that the profession may hear further from Mr. Goodrich along these lines, and that he will extend his clever observations and give us and himself the satisfaction of checking, or, if necessary, revising his mathematics.

Mr. Carlin. JOSEPH P. CARLIN, Jun. Am. Soc. C. E. (by letter).—In an article by the writer a description is given of some tests of piles, in connection with the construction of a sea-wall at the Annapolis Naval Academy, of which the following is an abstract:

Tests Nos. 1 and 2 were on the same pile, although the second test was on the pile after it had been driven 6 ft. further.

The original borings had indicated hard bottom at a uniform depth of 40 ft. below the river bed, excepting at one point, where they showed a depth of mud of 70 ft., with 7 ft. more of mud and sand before hard bottom was reached. This point, therefore, was selected for the site of the tests.

The usual data were taken during the driving. Then the head of the pile was squared and dowelled, and a timber frame, slung by means of wire-rope lashings, was securely fastened about the 3-in. steel dowel. To prevent lateral swaying, four guys were run out from the head, and their ends made fast to powerful kedge anchors. These guys were very nearly horizontal. The pile was then loaded with

* *The Engineering Record*, May 11th, 1901.

anchor chains and shot, each shot having been weighed separately and tagged. The frame weighed more than 9 tons. Mr. Carlin.

The sea-wall, along the site of the tests, has been finished. For about 200 ft. of wall the piles were in sand, and there has been no settlement. The next 100 ft., however, was in mud (Test No. 3), and there has been a settlement of 10 ins., which was subsequently arrested by driving additional re-enforcement piles of greater length, and blocking up from them under the wall.

In conclusion, the writer believes that, while the first two tests indicated fair results, the third demonstrated that, considered independently, the Wellington formula, or any other, is practically useless. The fourth and fifth tests give a striking lack of uniformity in the results.

It seems to be very necessary that the conditions surrounding the pile be the same as will be the case, ultimately, in the permanent structure; and that this test pile be observed during a period as long as the opportunity will permit, certainly not less than two or three months. If it be not possible to apply this time test, a carrying-capacity experiment would be no more satisfactory than the resort to the ordinary penetration records, together with an intelligent investigation of borings, both governed by experience with variable conditions.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

SOME DEVICES FOR INCREASING THE ACCURACY OR RAPIDITY OF SURVEYING OPERATIONS.

Discussion.*

By Walter Loring Webb, Assoc. M. Am. Soc. C. E.

Mr. Webb. Walter Loring Webb, Assoc. M. Am. Soc. C. E. (by letter.)—The writer feels gratified at the interest in the subject which has evidently been aroused by the paper. A large part of the discussion consists of the description of similar "devices for increasing the accuracy or rapidity of surveying operations," and needs no comment. The discussion, however, has developed the need for some further explanations. The plane-table alidade described in the paper was an old-style instrument, having originally a fixed vertical arc on the standard and a vernier arm rigidly attached to the telescope axis. The accuracy of the vertical angle depended on the leveling of the plane-table board. To have adopted the essential features of the United States Geological Survey alidade or the United States Coast and Geodetic Survey alidade (Figs. 1 and 2, Plate XIV) would have required an unprofitable reconstruction of an old instrument. In fairness to the design, however, it should be pointed out that, as the amplitude of motion of the vernier arc is very small, it was possible to place the vernier level between the standards, where it is well protected from accidental blows, and the writer believes that the design shown is as free from probable

* Continued from March, 1902, *Proceedings*. See December, 1901, *Proceedings*, for paper on this subject by Walter Loring Webb, Assoc. M. Am. Soc. C. E.

disturbances of adjustments as some of the others, although the newer types have unquestioned advantages; and, after all, it was the principle of a quickly adjustable vernier to which the writer wished to call attention, and, at the time that the University of Pennsylvania plane-table alidade was thus modified (several years ago) according to the writer's plans, he had never seen even an illustration of a similar device. Mr. Webb.

There is no need of adopting a special method of numbering the figures on the two verniers on a shortened vertical arc, as a means of distinguishing positive and negative vertical angles. If the line of collimation is so nearly level that any doubt exists as to the direction of its slope, a mere glance at the large bubble underneath the telescope will instantly answer the question beyond a possibility of confusion.

It is possible that greater accuracy is obtainable when a long striding level is used on a plane-table telescope and the telescope is first leveled for each "shot;" but it should be remembered that, after the telescope has been leveled, it must be raised or lowered until the horizontal cross-wire is at the proper reading on the rod. While taking that reading, there is nothing to indicate whether the table may have been jarred while the telescope was being adjusted, or whether some slight knock which it received had any appreciable effect in altering its adjustment. By the other plan, the vernier level will always indicate the leveling of the table. By one method the telescope must actually be brought level between every shot, besides reading the vernier. By the other method no time is necessarily lost. The vernier level will at once indicate whether a true vertical angle may be obtained, regardless of the precise leveling of the table itself. Frequently, several shots may be taken without re-leveling, and even, when necessary, a mere touch of the adjusting screw, made very quickly, will suffice to restore the adjustment. Practical experience with this device has shown this to be the case. The loss in time due to re-leveling for every shot, therefore, is much more than that admitted by Mr. Matthes on page 281.*

The stadia slide rule was of course designed to obtain differences of elevation as a function of $\frac{1}{2}$ sin. 2α, and that is its principal use. The comment regarding sin.$^2\alpha$, in the paper, was made to show the desirability of obtaining a function of sin.$^2\alpha$, rather than a function of cos.$^2\alpha$, which is the function obtained on most other stadia slide rules.

The writer admits that a greater range of vertical adjustment of the tape tension apparatus would have been desirable. Experience has shown that the range for lateral and longitudinal adjustment is ample, and that it simply requires more care in setting up the apparatus in its proper place to get it within the range of the vertical adjustment.

* *Proceedings*, Am. Soc. C. E., for March, 1902.

Vol. XXVIII. APRIL, 1902. No. 4.

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PAPERS AND DISCUSSIONS.

LINE AND SURFACE FOR RAILWAY CURVES.

Discussion.*

By Messrs. James K. Geddes and Charles A. Morse.

Mr. Geddes. James K. Geddes, M. Am. Soc. C. E. (by letter).—The transition spiral described by Mr. Wentworth seems to be well adapted, indeed, to the revision of lines where the track has already been laid, in that, as a rule, it does a minimum amount of violence to the original location. It would seem to be much less complicated than such spirals as the Searles, and fully as easy to stake out when once the necessary computations are made.

However, like nearly all transition curves so far presented to the professional public, it seems to be objectionable on account of the difficulty of calculating and laying out the revised line, and keeping the track to proper alignment after the change has been made. Few railways in this country, as yet, can keep a force of engineers in the field all the time giving centers to the track men, and such curves, even when monumented, would be difficult or impossible to keep in proper alignment by the average track force. If the transition curve could be made comparatively short, and simple tables and rules worked out for the cases likely to occur in practice, so that, when once located, the section men could keep the curve in proper alignment, much would be done to popularize this desirable curve. As it is, the aver-

* This discussion (of the paper by Charles C. Wentworth, M. Am. Soc. C. E., printed in *Proceedings* for February, 1902), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to May 24th, 1902, will be published subsequently.

age railway man—whether he be an engineer or not—with his strenuous life, is very prone to fight shy of transition curves, with a lot of formulas that are simple enough, perhaps, had he the time to consider them carefully as to their adaptability to his particular needs, and had he track men who could handle the curves as they do other routine track matters. Mr. Geddes.

CHARLES A. MORSE, M. Am. Soc. C. E. (by letter).—The author shows by his diagrams that he carries the low rail at the grade line and puts all the elevation in the outer rail. The Committee on "Track," in the Third Annual Convention of the Maintenance Association, made a similar recommendation, and it was accepted by the Convention without a word of discussion, which would seem to indicate that it was the practice on most railroads, or that the matter had been given little thought. Mr. Morse.

The practice originated with track men, when engineers on maintenance were not employed to any extent, and, under the circumstances, was the best they could do, as they had to have one rail to grade, to surface the track; but even then it was recognized that it increased the curve resistance, and this was prevented, by some track men, by running the outside or upper rail to grade and lowering the inside rail to get the elevation.

This could not be done without a good deal of expense, except in cases where the track was being raised several inches, and the result was the general use of the inside rail as a grade rail.

The cause of this practice, however, has disappeared on the larger roads at the present time, as engineers are considered as a necessary part of the maintenance force, and are called upon to re-center curves whenever they get to riding poorly, and also to set stakes for the proper elevation of the "outer rail." Everyone who has had occasion to plot a profile of a piece of track for the purpose of laying ballast grades has noticed the "hump" in the surface of the plotted center-line elevations, caused by all the elevation being given to the outer rail, and could not fail to see the effect on the train resistance at that point.

The grade is compensated on curves to offset the curve resistance, but, when all the elevation is given to the outer rail, the first 200 or 300 ft. of the curve has really a heavier grade than the maximum on the tangent next to it.

The result of this practice is the too common idea that the train resistance is increased for slow trains, when the track is elevated for fast passenger service, but the fault is in the way in which the elevation is put up, and not in the fact that there is elevation given.

Elevation on curves should be divided. The outside rail should be elevated one-half and the inside rail depressed one-half of the full

Mr. Morse. amount of elevation required for the speed of the fast train, and in this way the center of the track is kept at the true grade, and the loaded car does not have to be raised, but follows the compensated grade line, as laid down on the profile.

While stakes are being set, it is as easy to set them this way as the other, and they would not require re-setting any oftener than the easement curves would require re-centering, and this could be done at the same time.

While, perhaps, it is not advisable to lower track to get the depression for the inside rail, yet most roads are constantly raising track, and the desired result could gradually be obtained by holding the inside rail down and not lifting it at all, and in this way, in two or three surfacings of the curve, the elevation would be divided so that half would be above and half below the grade line. On roads where ballasting is being done, there is no trouble in staking it at once.

Why this old track man's expedient for elevating track should have survived and be recommended in this day of improvement, and especially when tonnage is the great question of the day, can be explained only by the fact that it is one of the small things which have not been looked after, but when it is given as good practice, by maintenance associations and writers on track work, it is time to call a halt and look into the matter.

To illustrate the effect on a tonnage train of the full elevation being given to the outer rail, take the case of a 2° 30′ curve on a maximum grade of 0.80 ft., which is put up for a passenger train speed of 60 miles per hour. The outer rail would be elevated 6 ins., and the center of the track would be raised half of this, or 0.25 ft. Now, if the easement is 200 ft. long, the rate of the grade on the first 100 ft. of easement would be 0.885 ft., and if the grade was compensated 0.05 ft. per degree, the rate on the second 100 ft. would be 0.845, whereas the profile grade on the first 100 ft. is 0.76 and on the second 100 ft. 0.72; in other words, the maximum grade is exceeded at the very point where compensation is required.

A train coming upon a curve put up in this way, when its speed is reduced to 10 or even 6 miles per hour, and it is pulling every ton it is rated for, feels this increase of grade, and is slowed up and often stalled before getting far on the curve. The lighter the maximum grade, the greater is the resistance to tonnage trains when all the elevation is obtained by raising the outer rail.

The increase of the grade on the easement to a curve is the more objectionable from the fact that it is on this part of the curve that the greatest resistance is felt from the friction of the body of the car on its side bearings. As soon as the elevation begins, the center of gravity of the load is moved toward the inside rail, the load comes

down on the side bearings on that side, and as the radius of the curve on the easement is constantly changing, so is the angle between the truck and the body of the car, and the pressure on the side bearings tends to prevent this movement and retard the speed of the train. After the car gets on the regular curve, the angle of the truck remains constant, the movement on the side bearings is small and its effect is less. Mr. Morse.

That this advantage to tonnage trains is recognized and taken into account is shown by the fact that one of the great systems of the country, which is spending large amounts in grade reduction to help its train-haul, and which is building several hundred miles of new road, is giving the surface of its banks on curves an elevatien of 2% of the width of roadbed per degree of curve, raising the outside one-half and depressing the inside one-half, thus making the center of the roadbed throughout on profile grade.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXVIII. No. 5.

MAY, 1902.

Edited by the Secretary, under the direction of the Committee on Publications.

CONTENTS.

NEW YORK 1902.

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Special Committees.

ON ANALYSIS OF IRON AND STEEL:—Sub-Committee of the American Society of Civil Engineers (of the International Committee on Standards for the Analysis of Iron and Steel, of which Prof. J. W. Langley is Chairman)—Charles B. Dudley, William Metcalf. Thomas Rodd.

ON UNITS OF MEASUREMENT:—George M. Bond, William M. Black, R. E. McMath, Charles B. Dudley, Alexander C. Humphreys.

ON UNIFORM TESTS OF CEMENT:—George S. Webster, George F. Swain, Alfred Noble, W. B. W. Howe, Louis C. Sabin, S. B. Newberry, Clifford Richardson, Richard L. Humphrey, F. H. Lewis.

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - - - 583 Columbus.
CABLE ADDRESS, - "Ceas, New York."

Vol. XXVIII. MAY, 1902. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

CONTENTS:

MINUTES OF MEETINGS.

OF THE SOCIETY.

May 7th, 1902.—The meeting was called to order at 8.45 P. M., Frank C. Osborn, Director, Am. Soc. C. E., in the chair; Charles Warren Hunt, Secretary; and present, also, 115 members and 20 guests.

The minutes of the meetings of April 2d and 16th were approved as printed in *Proceedings* for April, 1902.

A paper by George S. Webster and Samuel Tobias Wagner, Members, Am. Soc. C. E., entitled "The Pennsylvania Avenue Subway and Tunnel, Philadelphia, Pa.," was presented by Mr. Webster, and illustrated with lantern slides.

A written discussion by Joseph M. Wilson, M. Am. Soc. C. E., was presented by the Secretary, and the paper was discussed orally by Messrs. Charles G. Darrach, William B. Parsons and George S. Webster.

Ballots for membership were canvassed, and the following candidates were elected:

As Members.

George Ansel Carpenter, Pawtucket, R. I.
Charles Henry Clark, Utica, N. Y.
John Ernst Ericson, Chicago, Ill.
Benjamin Truman Fendall, Baltimore, Md.
Henning Fernstrom, New York City.
William Charles Gotshall, New York City.
Herbert Thomas Grantham, Philadelphia, Pa.
Henry Arthur Hall, Boston, Mass.
Arthur Stanley Ives, Philadelphia, Pa.
Charles Willauer Kutz, Washington, D. C.
Edwin John Rosecrans, New York City.
Louis Carlton Sabin, Port Huron, Mich.
Francis Clinton Shenehon, Detroit, Mich.
George Way Swinburne, Jr., New York City.
John William Woerman, Sheffield, Ill.

As Associate Members.

Henry Erskine Baker, Watertown, N. Y.
George Elliot Browning, Trichur, S. India.
Harrison Prescott Eddy, Worcester, Mass.
Louis Amedee Gueringer, Marlin, Tex.
Isaac Onward Harper, Baltimore, Md.
Theodore Ely Knowlton, Watertown, N. Y.
Charles Real Olberg, Washington, D. C.
Archibald Livingstone Parsons, Washington, D. C.
Harold Tait, Long Island City, N. Y.
Morrell Vrooman, Gloversville, New York.
Ernest Woodbury Wiggin, New Haven, Conn.
Arthur John Wills, Harrisburg, Pa.
Julius Herman George Wolf, San Francisco, Cal.

The Secretary announced the election of the following candidates by the Board of Direction on May 6th, 1902:

As Associates.

John Laroy Mann, Hanover, N. H.
John Burton Stouder, Mason City, Iowa.

As Juniors.

Walter Esmond Barnes, New York City.
Arthur Emil Wenige, New York City.
John Hough Wickersham, New York City.

The Secretary announced the death of the following members:

JAMES ELLISON MILLS, elected Member, Feb. 3d, 1896; died July 25th, 1901.

REGINALD MCKEAN, elected Assoc. M. May 2d, 1894; died Oct. 15th, 1901.

The Secretary announced the details of the programme of the Annual Convention, and also some information relative to the special train from New York to Washington.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

May 6th, 1902.—Vice-President Schneider in the chair; Charles Warren Hunt, Secretary; and present, also, Messrs. Briggs, Croes, Knap, Kuichling, O'Rourke, Osborn and Seaman.

The President was authorized to appoint a Committee to award prizes for the year ending with the month of July, 1902.

Applications were considered and other routine business transacted.

Two candidates for Associate and three for Junior were elected.*

Adjourned.

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* See page 148.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, June 4th, 1902.—8.30 P. M.—At this meeting, ballots for membership will be canvassed, and a paper by George L. Dillman, M. Am. Soc. C. E., entitled "A Proposed New Type of Masonry Dam," will be presented for discussion.

This paper was printed in the *Proceedings* for April, 1902.

Wednesday, September 3d, 1902.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper by R. C. McCalla, M. Am. Soc. C. E., entitled "Improvement of the Black Warrior, Warrior and Tombigbee Rivers, in Alabama," will be presented for discussion.

This paper was printed in the *Proceedings* for April, 1902.

Wednesday, September 17th, 1902.—8.30 P. M.—At this meeting, a paper by James N. Hazlehurst, M. Am. Soc. C. E., entitled "The Maintenance of Asphalt Streets," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ACCESSIONS TO THE LIBRARY.

From April 9th to May 6th, 1902.

DONATIONS.*

THE RAILWAY TRANSITION SPIRAL.

By Arthur N. Talbot, M. Am. Soc. C. E. Third Edition, Revised. Leather, 7 x 4 ins., 110 pp. New York, Engineering News Publishing Co., 1901. $1.50.

The writer states that the treatment given in this book has been quite widely used on the railroads of the United States, and has been commended by many engineers for its simplicity, convenience and flexibility. The conceptions and methods used are similar to those of ordinary circular railroad curves. In this revision attention has been given to illustrative examples and explanations; the tables have been extended and a treatment of the uniform chord length method and of street railway spirals has been added. The Contents are: Nomenclature; Theory; Summary of Principles; Description and Use of the Tables; Choice of *a* and Length of Spiral; Location of P. S., P. C. C., and P. C.; Laying Out of the Spiral by Co-ordinates; Location by Transit and Deflection Angles; Application to Existing Curves; Compound Curves; Miscellaneous Problems; Uniform Chord Length Method; Street Railway Spirals; Explanation of Tables; Tables.

LOGARITHMIC TABLES OF THE MEASURES OF LENGTH.

Extending from 0 to 50 Feet at Intervals of One-Sixteenth of an Inch. By Thos. W. Marshall. Leather, 3 x 6 ins., 106 pp. New York, The Engineering News Publishing Company, 1902. $2.00.

It is stated in the preface that all the tables have been carefully checked several times—both before and after they were set in type—and it is believed that all errors of greater magnitude than one unit in the last decimal place have been eliminated.

A TEXT-BOOK ON ROOFS AND BRIDGES.

Part III. Bridge Design. By Mansfield Merriman and Henry S. Jacoby. Fourth Edition, Rewritten. Cloth, 9 x 6 ins., 8 + 374 pp., plates, illus. New York, John Wiley & Sons, 1902. $2.50.

This edition has been entirely rewritten in order to bring the subject fully up to date. In so doing, it has been the constant aim of the authors, not only to give the latest details of modern bridge practice, but also to set forth the reasons for such practice in a manner especially adapted to the needs of students and young engineers. The preface states that in the descriptions of the details of plate-girder and truss bridges only those are given which may be properly claimed as standard in the best recent practice. A new feature of the book consists in lists of references to engineering periodicals where more extended descriptions and applications of various details may be found. The Contents are: History and Literature; Principles of Economic Design; Bridge Contracts and Office Work; Bridge Shops and Shop Practice; Tables and Standards; Details of Plate-Girder Bridges; Design of a Plate-Girder Bridge; Details of Railroad Pin Bridges; Design of a Pin Truss Bridge; Design and Detailing of a Highway Bridge; Railroad Riveted Bridges. There is an index of four pages.

IRRIGATION IN THE UNITED STATES.

By Frederick Haynes Newell, M. Am. Soc. C. E. Cloth, 8 x 5 ins., 19 + 417 pp., 62 plates, illus. New York, Thomas Y. Crowell & Co., 1902. $2.00. (Donated by the Author.)

The writer has been continuously engaged for the past twelve years in conducting investigations of the extent to which the arid regions can be reclaimed by irrigation, ascertaining the cost and capacity of reservoirs, measuring the flow of rivers useful for power, irrigation, and other industrial purposes, and mapping the artesian or underground waters. The attempt is here made to bring together, in as non-technical a manner as possible, the results of this study and experience. A somewhat elementary and popular description of irrigation and of the devices for obtaining and distributing water is given, more space being devoted to the crude, but effective, home-made contrivances than to the elaborate and expensive machinery purchased from manufacturers. The chapter headings are: Reclamation of the Public Lands; The Arid Regions;

* Unless otherwise specified, books in this list have been donated to the Library by the Publisher.

Surface Waters; Conveying and Dividing Stream Waters; Reservoirs; Methods of Irrigation; Underground Waters; Pumping Water; Advantages and Disadvantages of Irrigation; Irrigation Law; States and Territories of the Arid Regions; States of the Semi-Arid Region; Humid Regions; Conclusion. There is an index of eleven pages.

DIE NATÜRLICHEN NORMALPROFILE DER FLIESSENDEN GEWÄSSER.

Vortrag gehalten in der Vollversammlung des Oesterr. Ingenieur- und Architekten-Vereines am 25. Jänner 1902 von Richard Siedek. Paper, 9 x 6 ins., 21 pp., illus. Wien, Wilhelm Braumüller, 1902.

THE LAW OF CONTRACTS.

A Text-Book for Technical Schools of Engineering and Architecture. By John Cassan Wait, M. Am. Soc. C. E. Cloth, 9 x 6 ins., 14 + 331 pp. New York, John Wiley & Sons, 1901. $3.00. (Donated by the Author.)

The chapters here presented are the substance of a course of lectures delivered by the author some years ago before the technical classes in engineering and architecture at Harvard University. They were first embodied in his book on "Engineering and Architectural Jurisprudence," but, as that work is more comprehensive than is required for a textbook, this abridged edition has been issued. The preface states that the present volume contains the essential principles upon which valid contracts depend, and the main features of the statutes which modify and limit the obligations of contracts, and also. in a fairly complete and concise form, the law of bidding and letting. Almost all the illustrations used and the cases cited as authorities are those which have arisen in engineering and architectural work. The Contents are: Essential Elements of a Contract; Legal and Illegal Contracts; The Parties to a Contract; Law of Contracts; Essential Elements of a Contract; General Statutes Limiting the Law of Contracts; The Rights and Liabilities of Bidders for Public Work; Bids and Bidders; Work for Private Parties; Employment or Engagement of Engineer or Architect; Property of Engineers or Architects in Designs or Inventions; Liability of Engineer or Architect as a Professional Man; Liability of Engineer or Architect when his Functions are Judicial or Discretionary; Liability of an Engineer or Architect when a Public Officer; Compensation of Engineers and Architects; Employment of an Engineer or Architect as an Expert Witness. There is an index of twenty-seven pages.

A TREATISE ON THE PRESERVATION OF METAL.

A Practical, Comprehensive Hand-Book for Architects, Builders, Mechanical and Civil Engineers, Painters, Metal Workers, Property Owners, and Anyone Supervising the Maintenance of Steel and Iron Structures. By Lionel M. Stern. Paper, 8 x 5 ins., 21 pp. Central Printing and Publishing House, Harrisburg, Pa., 1901. 50 cents. (Donated by the Author.)

The following gifts have also been received:

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BY PURCHASE.

A Handbook for the Electrical Laboratory and Testing Room. By J. A. Fleming, M. Inst. E. E. Volume I. New York, The D. Van Nostrand Company; London, "The Electrician" Printing and Publishing Company, Limited, 1901.

Central Electrical Stations: Their Design, Organization, and Management. By Charles Henry Wordingham, M. Inst. C. E.; M. Inst. M. E.; M. Inst. E. E.; M. Am. Inst. E. E. London, Charles Griffin and Company, Limited, 1901.

Electrical Engineering Testing; A Practical Work for Second and Third Year Students, Engineers, and Others. By G. D. Aspinall Parr, M. Inst. E. E.; A. M. Inst. M. E. London, Chapman and Hall, Limited; Philadelphia, J. B. Lippincott Co., 1902.

Production et Distribution de l'Énergie pour la Traction Électrique). Par Henry Martin. Paris, Ch. Béranger, 1902.

Contribution à l'Étude des Alliages. Par W. H. Bakhuis, Roozeboom, Ad. Carnot, G. Charpy, H. Le Chatelier, H. Gautier, Ed. Goutal, Guillaume F. Osmond, Roberts Austen, Sklodowska Curie, sous la Direction et le Controle de la Commission des Alliages, 1896–1900. Paris, Chamerot et Renouard, 1901. (Société d'Encouragement pour l'Industrie Nationale.)

Die Bewetterung der Bergwerke. Von Robert Wabner. (With Atlas.) Leipzig, Arthur Felix, 1901.

Mitteilungen über Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, insbesondere aus den Laboratorien der technischen Hochschulen, herausgegeben vom Verein deutscher Ingenieure. 3 vol. Berlin, Julius Springer, 1901.

Nuevo Diccionario de Pronunciación de las Lenguas Inglesa y Española. Por Mariano Velázquez de la Cadena. Nueva Edición, Cuidadosamente Revisada y Aumentada por Edward Gray y Juan L. Iribas. Segunda Parte: Inglés-Español. Nueva York, D. Appleton y Compañía, 1902.

Who's Who in America. A Biographical Dictionary of Notable Living Men and Women of the United States, 1901–1902. Edited by John W. Leonard. Chicago, A. N. Marquise & Company, 1901.

Street-Cleaning and the Disposal of a City's Wastes : Methods and Results and the Effect upon Public Health, Public Morals, and Municipal Prosperity. By George E. Waring, Jr. New York, Doubleday & McClure Co., 1899.

A Manual of Practical Hygiene for Students, Physicians, and Medical Officers. By Charles Harrington. Lea Brothers & Co., Philadelphia and New York, 1901.

Municipal Sanitation in the United States. By Charles V. Chapin. Snow & Farnham, Providence, R. I., 1901.

Sanitary Engineering: A Practical Manual of Town Drainage and Sewage and Refuse Disposal. For Sanitary Authorities, Engineers, Inspectors, Architects, Contractors, and Students. By Francis Wood, A. M. Inst. C. E. London, Charles Griffin & Company, Limited; Philadelphia, J. B. Lippincott Company, 1902.

Sanitary Engineering of Buildings. By Wm. Paul Gerhard, M. Am. Inst. Archts. Vol. 1. New York, William T. Comstock, 1899.

A Dictionary of Architecture and Building, Biographical, Historical, and Descriptive. By Russell Sturgis, M. Am. Inst. Archts., and Many Architects, Painters, Engineers, and Other Expert Writers, American and Foreign. 3 vol. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1901.

Civil Engineering as Applied in Construction. By Leveson Francis Vernon-Harcourt, M. Inst. C. E. Longmans, Green & Co., London, New York and Bombay, 1902.

Der Schornsteinbau. Von Gustav Lang. 3 vol. Hannover, Helwing, 1896–1901.

Cement and Engineering News (to complete set). 7 vol., 20 nos.

Electrical Engineer (to complete set). 5 vol.

Electrical World and Engineer (to complete set). 11 vol.

Electrician (to complete set). 32 vol.

SUMMARY OF ACCESSIONS.

From April 9th to May 6th, 1902.

Donations (including 95 duplicates and 3 numbers completing volumes of periodicals)	460
By purchase (including 20 numbers completing volumes of periodicals)	109
Total	569

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
ALDERMAN, CHARLES ALDO, Interurban Union Station, Columbus, Ohio..	Assoc. M. M.	April 6, 1898 April 2, 1902
ANTHONY, CHARLES, Jr., Glenview, Hereford, England..........................		March 5, 1902
DUNHAM, CHARLES FREDERICK, Hotel Oxford, Denver, Colo............................		April 2, 1902
ERICSON, JOHN ERNST, City Engr., 604 Chamber of Commerce Bldg. (Res., 1914 Arlington Pl.), Chicago, Ill...........................		May 7, 1902
FERNSTROM, HENNING, Prin. Asst. Engr., N. Y. C. & H. R. R. R., Room 521, Grand Central Station, New York City.................		May 7, 1902
FREYHOLD, FELIX, Bureau of Equipment, Navy Dept., 236 First St., S. E., Washington, D. C.............	Assoc. M. M.	Sept. 2, 1891 April 2, 1902
GRANTHAM, HERBERT THOMAS, Structural Engr., 1622 Real Estate Trust Bldg., Philadelphia, Pa..................	Assoc. M. M.	Feb. 5, 1896 May 7, 1902
HANNA, JOHN VENABLE, Asst. Chf. Engr., Frisco System, North Side Office, Springfield, Mo....................	Assoc. M. M.	May 3, 1893 April 2, 1902
KUTZ, CHARLES WILLAUER, Capt., Corps of Engrs., U. S. A., Washington Barrracks, Washington, D. C..................................		May 7, 1902
MINER, CHARLES AUGUSTINE, 815 Witherspoon Bldg., Philadelphia, Pa....	Assoc. M. M.	April 7, 1897 Dec. 4, 1901
ROSENCRANS, EDWIN JOHN, (Jackson, Rosencrans & Canfield, Archts.), 160 Fifth Ave., New York City....................................		May 7, 1902
SABIN, LOUIS CARLTON, U. S. Asst. Engr., Federal Bldg., Port Huron, Mich.................................	Assoc. M. M.	Oct. 4, 1893 May 7, 1902
SERGEANT, GEORGE, Jr., Prin. Asst. Engr., Atlantic Ave. Impvt., L. I. R. R., 56 West 33d St., New York City.........................		April 2, 1902
SWINBURNE, GEORGE WAY, (Swinburne & Clark), 156 Fifth Ave., New York City.....		May 7, 1902

ASSOCIATE MEMBERS.

ATKINS, HAROLD BEDFORD, 22 William St., New York City.........................	April 2, 1902

		Date of Membership.
BLANCHARD, MURRAY,		
Jun. Engr., U. S. Lake Survey, U. S. Engr. Office, Campau Bldg., Detroit, Mich.		April 2, 1902
GESSNER, GUSTAVUS ADOLPHUS, Jr.,		
406 Kenilworth Ave., Toledo, Ohio		April 2, 1902
HARPER, ISAAC ONWARD,		
1608 Bolton St., Baltimore, Md.		May 7, 1902
KNOWLTON, THEODORE ELY,	Assoc.	Mar. 31, 1896
Care, St. Regis Paper Co., Watertown, N. Y.	Assoc. M.	May 7, 1902
PARSONS, ARCHIBALD LIVINGSTONE,		
Asst. Engr., U. S. Engr. Office, P. O. Box 455 (Res., 508 A St. N. E.), Washington, D. C.		May 7, 1902
SABINE, EDWARD DANA,		
Chf. Engr., American Pneumatic Service Co., Boston Pneumatic Transit Co., 115 Chauncey St., Boston, Mass		Feb. 5, 1902
SLAYTON, CHARLES ALBERT,		
Care, Chf. Engr., C., O. & G. R. R., Little Rock, Ark.		April 2, 1902
VROOMAN, MORRELL,		
City Engr., Gloversville, N. Y.		May 7, 1902
WILLS, ARTHUR JOHN,		
Commonwealth Trust Bldg., Harrisburg, Pa.		May 7, 1902
WILSON, HENRY FELIX, Jr.,		
(Wilson & Motley, Civ. and Min. Engrs.), 315 Chalifoux Bldg., Birmingham, Ala.		April 2, 1902

JUNIORS.

HAYDEN, EDWIN CLAPP,	
Prescott House, Everett, Mass	Oct. 1, 1901
TOENSFELDT, HANS CARL THOMAS,	
1550 Mississippi Ave., St. Louis, Mo.	April 1, 1902
WICKERSHAM, JOHN HOUGH,	
1 East 34th St., New York City	May 6, 1902

CHANGES OF ADDRESS.

MEMBERS.

APPLETON, ELLERY CUSHING	Westboro, Mass.
BAKER, WILLIAM EDGAR	170 Broadway, New York City.
BAXTER, FRANK EDWIN	Div. Engr., Rio Grande Western Ry., 1250 E. South Temple St., Salt Lake City, Utah.
BODY, JOHN BENJAMIN	Director, S. Pearson & Son, Ltd., Puente de Alvarado 15, City of Mexico, Mexico.
CAPLES, MARTIN JOSEPH	Treas. and Supt., Pocahontas Coal & Coke Co., 1219 Arcade Bldg., Philadelphia, Pa.

CREUZBAUR, ROBERT WALTER	Care, New York Continental Jewell Filtration Co., Mills Bldg., New York City.
CUMMINGS, ROBERT AUGUSTUS	Civ. Engr. and Contr., 609 House Bldg., Pittsburg, Pa.
FTELEY, ALPHONSE	Park Hill Ave., Park Hill, Yonkers, N. Y.
FUERTES, JAMES HILLHOUSE	Civ. and San. Engr., 140 Nassau St., New York City.
FULLER, WILLIAM BARNARD	Hydr. and San. Engr., 170 Broadway, New York City, and 299 Main St., Paterson, N. J.
HARROD, BENJAMIN MORGAN	Cotton Exchange Bldg., New Orleans, La.
HASKINS, WILLIAM JEWETT	Chf. Engr. of Sewers, New Rochelle, N. Y., and 120 Liberty St., New York City.
HERING, RUDOLPH	(Rudolph Hering and George W. Fuller, Hydr. Engrs. and San. Experts), 170 Broadway, New York City.
HOFF, OLAF	504 Grand Central Station, New York City. (Res., Tarrytown, N. Y.)
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KASTL, ALEXANDER EDWARD	Care, The Denver Union Water Co., Denver, Colo.
LEWIS, NELSON PETER	Chf. Engr., Board of Estimate and Apportionment, City Hall, New York City.
MACFARLANE, JAMES	Care, Cerro de Pasco Co., Cerro de Pasco, Peru.
PIERCE, HENRY	Supt., C. & O. R. R., Ronceverte, W. Va.
PRINCE, GEORGE THOMAS	Care, Davenport Water Co., Davenport, Iowa.
REED, MELVILLE EMERSON	Engr. in Chg., Seattle Terminals, G. N. Ry., Room 2, Metropolitan Blk., Seattle, Wash.
SMITH, MILLER ARMSTRONG	235 Lincoln Rd., Flatbush, Brooklyn, N. Y.
SPERRY, HENRY MUHLENBERG	Signal Engr. and Agt., The Union Switch & Signal Co., 143 Liberty St., New York City.
SULLIVAN, JOHN G.	Div. Engr., C. P. Ry., Bank of Hamilton Bldg., Winnipeg, Man., Canada.
TAYS, EUGENE AUGUSTUS HOFFMAN	Fuerte, Sinaloa, Mexico.
TUTTLE, ARTHUR SMITH	1050 Eighty-second St., Brooklyn, N. Y.

WHITFORD, OSCAR F. ....Box 81, Saratoga Springs, N. Y.
ZOOK, MORRIS ALEXANDER............Plainfield, N. J.

ASSOCIATE MEMBERS.

BANCE, CHARLES WILLIAM............Asst. Engr., Jersey City Water Supply Co., 308 Main St., Paterson, N. J.
BORIGHT, WILLIAM PARSONS...........2130 Green St., Philadelphia, Pa.
BROWN, ROBERT KING.................Engr., M. of W., San Pedro, Los Angeles & Salt Lake Ry., Los Angeles, Cal.
BRYSON, THOMAS BINES...............39 West 36th St., New York City.
FISH, JOHN CHARLES LOUNSBURY.....Ben Lomond, Santa Cruz County, Cal.
FULLER, GEORGE WARREN............(Rudolph Hering and George W. Fuller, Hydr. Engrs. and San. Experts), 170 Broadway, New York City.
GREGORY, JOHN HERBERT.............Div. Engr., Jersey City Water Supply Co., 299 Main St., Paterson, N. J.
GROSS, DANIEL WINGERD...............1300 Eutaw Pl., Baltimore, Md.
HEMMING, DUNKIN WIRGMAN...........502 West 143d St., New York City.
HENDRICKS, VICTOR KING.............74 Middle Drive, Woodruff Pl., Indianapolis, Ind.
HOBBY, ARTHUR STANLEY, Jr..........Mgr. and Engr., Guantanamo R. R., Guantanamo, Cuba.
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HORTON, THEODORE ....Care, Hering and Fuller, 170 Broadway, New York City.
HUTCHINSON, CARY TALCOTT...........Cons. Engr., 56 Pine St., New York City.
JARRETT, EDWIN SETON............. .Cons. Engr., 35 Nassau St., New York City.
LAVIS, FRED.........................Locating Engr., C., O. & G. R. R., Denison, Tex.
LEWERENZ, ALFRED COURTNEY.........Care, Bureau of Yards and Docks, Navy Dept., Washington, D. C.
MEAD, CHARLES ADRIANCE ....Upper Montclair, N. J.
PRUYN, FRANCIS LANSING..............13 Park Row, New York City.
ROSENBERG, FRIEDRICH.................316 Montgomery St., Jersey City, N. J.
SHAW, ENOS LARKIN..................2667 N. Ashland Ave., Chicago, Ill.
SPIELMAN, JOHN GODFREY............Fairfield, Iowa.
STENGER, ERNEST...... .... 267 South Lincoln Ave., Denver, Colo.
STRATTON, GEORGE DRAPER ....Asst. Engr., Western Div. Southern Pacific R. R., 1039 Union St., Oakland, Cal.
THOMPSON, CLARK WALLACE... ....708 Everett St., Portland, Ore.
TURNER, DANIEL LAWRENCE...........39 Broadway, New York City.
WEBSTER, ALBERT LOWRY.............Civ. and San. Engr., 82 Wall St., New York City.

JUNIORS.

Adams, Arthur........................Mo-i-Ranen, Helgeland, Norway.
Brown, Collingwood Bruce, Jr.......Chf. Engr's. Office, C. P. Ry., Montreal, Que., Canada.
Dufour, Frank Oliver.... ....Asst. Prof. in Chg., Civ. Eng. Dept., Univ. of Cincinnati, Cincinnati, Ohio.
Gifford, Harry Van Vleck...........Bradner, Ohio.
Granbery, Julian Hastings...........561 Walnut St., Elizabeth, N. J.
Hyde, William Herbert.............Care, Wm. Glyde Wilkins, Westinghouse Bldg., Pittsburg, Pa.
Merriman, Thaddeus.................Asst. Engr., Jersey City Water Supply Co., Boonton, N. J.
Pitts, Thomas Dorsey ....Chf. Draftsman, Tams & Lemoine, Naval Archts., 52 Pine St., Room 1200, New York City.
Price, Philip Wallis.............,....Care, G. N. Ry., Great Falls, Mont.
Ramsey, Edmund Payton ....Asst. Engr., First Div., Rapid Transit R. R. Comm., 13 Astor Pl., New York City (Res., 11 Flushing Ave., Brooklyn, N. Y.).
Raynor, Clarence Webster.... .....Box 385, Kansas City, Mo.
Veuve, Erle Leroy..................Asst. Engr., Pacific Electric Ry. Co., Los Angeles, Cal.

DEATHS.

Hamlin, Charles Edward...........Elected Associate Jan. 2d, 1894; died Jan. 20th, 1902.
McKean, Reginald. ....Elected Associate Member May 2d, 1894; died October, 1901.
Mills, James Ellison.................Elected Member Feb. 3d, 1886; died July 25th, 1901.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(April 9th to May 6th, 1902.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Eng., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Can.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.*
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Institute, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 35c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des Ecôle Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mecanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Eng., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c
(47) *Mechanical Engineer*, Manchester, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Institute of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.

LIST OF ARTICLES.

Bridge.

Calculation for a Suspension Bridge. (21) Apr.
The New Bridge over the Amou Daria River on the Trans-Caspian Railway.* A. Zdziarski. (13) Apr. 10.
The Strengthening of Early Iron Bridges.* (12) Serial beginning April 11.
The Riverside Drive Viaduct over Ninety-sixth Street, New York.* (14) Apr. 12.
A Simple Method of Calculating Continuous and Constrained Beams. Edward Godfrey. (13) Apr. 17.
Defective Bridge Construction in the Prairie States.* Daniel B. Luten. (13) Apr. 17.
The Painting and Sand-Blast Cleaning of Steel Bridges and Viaducts. George W. Lilly, Assoc. M. Am. Soc. C. E. (Paper read before the Engineers' Club of Columbus, O.) (13) Apr. 24.
Some Observations on the Deep Pneumatic Work of the New East River Bridge Foundations. Edwin Duryea, Jr., M. Am. Soc. C. E. (13) May 1.
Specified Loadings for Railroad Bridges. Ward Baldwin, M. Am. Soc. C. E. (15) May 2.
Moving the Ft. Wayne Bridge at Pittsburg.* (18) May 8.
Cable-making on the New East River Bridge, New York. (14) May 8.
Notice sur les Travaux de Consolidation du Pont sur la Canche à Etables (Pas-de-Calais). Transformation en Cantilever d'une Poutre à Travée Solidaire. M. Houpeurt. (43) 4e Trimestre, 1901.

Electrical.

Static Strains in High Tension Circuits and the Protection of Apparatus.* Percy H. Thomas. (42) Mar.
An Apparatus for the Rapid Comparison of Voltmeters. F. A. Laws and W. D. Coolidge. (7) Mar.
The Gardner Electric Drill.* (22) Apr. 4.
The Phase Displacement of Alternators and Parallel Running. H. G. Leake. (26) Serial beginning April 4.
Tests on the Nernst Lamp. R. P. Hulse. (Paper read before the Birmingham Section, Inst. Elec. Engrs.) (47) Apr. 5.
Electric Wiring Methods of To-day, with Particular Reference to Conduit Systems. Fred. Bathurst, A. M. I. E. E. (26) Apr. 11.
Grounding of High Potential Systems.* J. D. Nies. (27) Apr. 12.
The Storage Battery in the Commercial Operation of Electric Automobiles.* W. H. Palmer, Jr. (27) Apr. 12.
Air-Spaced Cables: Their Treatment and Use. G. E. Fletcher, Assoc. M. Inst. C. E. (Paper read before Inst. Elec. Engrs.) (47) Apr. 19.
Ratio of Transformation in Three-Phase Circuits. Wm. A. Del Mar. (27) Apr. 19.
Electric Cranes at the Middlesborough Docks. Frank C. Perkins. (62) Apr. 24.
Electro-Magnetic Oscillations. Rankin Kennedy. (26) Serial beginning Apr. 25.
A Central Station Isolated Plant.* (27) Apr. 26.
Alternating Current Engineering.* B. A. Behrend. (10) May.
Electricity in Austria-Hungary.* Felix Horschitz. (27) May 3.
The Synchronous Converter as Voltage Controller. M. Seidner. (27) Serial beginning May 3.
Dipositif Protecteur pour les Installations Électriques à Lignes Aériennes parcourues par des Courants de Haute Tension. MM. Krizick et Fischer-Hinnen. (43) 4e Trimestre, 1901.
La Fabrication des Charbons Électriques. (34) Apr.
Usine Hydro-Électrique de Hagneck (Suisse).* Henry Martin. (33) April 12.

Marine.

Torsional Vibration of Shafts. L. Gümbel. (Paper read before the Inst. of Naval Archts.) (11) Apr. 11.
The Navipendular Method as applied to some Warships of Different Classes. G. Russo. (Paper read before Inst. of Naval Archts.) (11) Serial beginning Apr. 18.
On the Corrosion of Condenser Tubes and Sea-Water Conductors.* Ernst Cohen. (Paper read before the Inst. of Naval Archts.) (11) Apr. 25.

Mechanical.

Speed Regulation of Prime Movers and Parallel Operation of Alternators. Charles P. Steinmetz. (42) Mar.
Parallel Operation of Engine-Driven Alternators. W. L. R. Emmett. (42) Mar.
Separation of Oil from Condensed Steam.* J. R. Bibbins. (1) Mar.
Condensing Engine Practice.* Alex. Dow. (1) Mar.
The Loss of Heat from Covered Steam Pipes. Charles P. Paulding. (8) Apr.
The Ferranti Vertical Compound Engine.* (64) Apr.
Boiler Repairs.* W. J. Ranton. (64) Apr.
Metallic Packings for Piston and Valve Rods.* C. G. Robbins. (64) Apr.
The Investigation of the Penberthy Boiler Explosion.* R. C. Carpenter. (64) Apr.
Circulation in Water-Tube Boilers. Wm. H. Booth. (26) Apr. 4.
Distortion in Boilers Due to Overheating. C. E. Stromeyer. (11) Apr. 4; (12) Apr. 4.
High-Speed Engines. (12) Apr. 4.

* Illustrated.

Mechanical—Continued.

Evolution of the Shaft Governor. R. C. Carpenter. (Paper read before the Engine Builders' Assoc.) (47) Serial beginning Apr. 5.
Boiler Scale Solvents. (62) Apr. 10.
Production of Illuminating Gas from Coke Ovens.* F. Schniewind. (22) Apr. 11.
Modern Practice and Its Results in the Drawing of Wire Rods into Wire. William Garrett. (22) Apr. 11.
The Scott-Elliot Furnace Equipment for Steam Boilers.* (11) Apr. 11.
Guarding Textile Machinery.* Samuel R. Platt. (Paper read before the Inst. of Mech. Engrs.) (11) Serial beginning Apr. 11.
Large Gas Engines for Driving Electric Generators. A. R. Bellamy, M. I. E. E. (47) Apr. 12.
The Distribution of Artificial Gas under High Pressure. (14) Apr. 12.
The Mechanical and Heating Apparatus in the New Century Apartment House, New York.* (14) Apr. 12.
Coke Handling.* (24) Apr. 14.
Wheel Gearing.* W. H. Thornbery. (22) Serial beginning Apr. 18.
Circulation in Water-Tube Boilers. A. C. Elliott. (11) Apr. 18.
Some Notes on Steam Turbines.* F. J. Warburton. (19) Apr. 19.
High Speed for Shafting and Belting. Charles A. Hague, M. Am. Soc. C. E. (14) Apr. 19.
Distortion in Boilers Due to Overheating. C. E. Stromeyer. (Paper read before the Inst. of Naval Archts.) (47) Serial beginning Apr. 19.
The Mechanical Plant of the Broad Exchange Building, New York.* (14) Apr. 19.
Oil Gas and Oil Incandescent Lighting. Vivian B. Lewes. (66) Apr. 22.
The Cockerill Variable Cut-Off Gear for Gas Engines.* (20) Apr. 24.
Motor Car Exhibition at Islington.* (12) Serial beginning Apr. 25.
New Cranes in German Dockyards.* (12) Apr. 25.
Guarding Machine Tools.* W. H. Johnson. (Paper read before the Inst. of Mech. Engrs.) (11) Apr. 25.
Standardization of Pipe Flanges and Flanged Fittings.* Robert E. Atkinson. (Paper read before the Inst. of Mech. Engrs.) (11) Serial beginning Apr. 25.
The Wigzell Balanced Engine.* R. J. Isaacson. (47) Apr. 26.
An American Poppet-Valve Engine.* (64) May.
The Fuel Value of Residuals. Charles F. Prichard. (Paper presented to the Amer Gas Light Assoc.) (64) May.
The Operation of the Modern Grain Elevator.* Day Allen Willey. (9) May.
Gas-Power Plants for Mining and Smelting.* Hawley Pettibone. (10) May.
The Alberger Cooling Towers.* (20) May 1.
New Airship under Construction for the British War Office.* (46) May 3.
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The Oxford Paper Mills.* (14) May 3.
Les Charbons Américains en France. A. de Geunes. (32) Feb.
Les Appareils de Sûreté des Chaudières à Vapeur: Soupapes de Sûreté. F. Sinigaglia. (37) Mar.
Transporteur Aérien sur Cables de l'Usine Hydro-électrique de Vouvry (Suisse).* Alfred Boudon. (33) Mar. 29.
Basculeur Automatique, Système Malissard-Taza, Installé aux Mines de Marles, pour l'Embarquement Mécanique des Charbons.* (34) Apr.
Machines à Percer Radiales Américaines Fosdick & Holloway.* (36) Apr. 10.
Étude sur Pompe Sèche. E. Portemont. (36) Apr. 10.
Théorie de la Vapeur Surchauffée. Loffet. (36) Serial beginning Apr. 10.

Metallurgical.

Upon the Constitution of Binary Alloys. John Alexander Mathews. (3) Serial beginning Jan., ending Mar.
An Improved Method of Supplying Water to Blast Furnace Tuyeres and Coolers.* W. J. Foster. (22) Apr. 11.
An Automatic System of Sampling.* Paul Johnson. (16) Apr. 12.
The Rader Blast Furnace.* (62) Apr. 17.
The False Witness of the Test Bar. Robert Buchanan. (9) May.
The Foundry Cupola and How To Manage It. Robert Buchanan. (10) May.
Low-Grade Iron Ores for the Smelting Furnace, Concentrating and Briquetting. Thomas Benjamin Grierson. (10) May.
Les Convertisseurs pour Cuivre. P. Jannettaz. (32) Feb.
Hauts Fourneaux d'Eliza, à Pittsburg (États-Unis).* Aug. Dutreux. (33) Apr. 5.

Military.

Are Disappearing Guns Essential to the Efficient Defense of Our Seaports?* Edwin R. Stuart and W. R. Hamilton. (44) Mar.
Reconstruction des Formes de Radoub de Pontaniou dans l'Arsenal de Brest. G. Richou. (32) Feb.

Mining.

What is the Least Possible Waste in Working Coal? James Barrowman. (59) XXIII, Part 3.

* Illustrated.

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The Use of Compressed Air in Mining. T. W. Barber, M. I. C. E. (22) Apr. 4.
Driving the Newhouse Tunnel.* H. Foster Bain. (16) Apr. 19.
The Divergence of Long Plumb Lines at the Tamarack Mine.* F. W. McNair. (16) Apr. 26.

Miscellaneous.

The National Bureau of Standards. S. W. Stratton. (2) Apr.
A Report on the Metric System. (20) Apr. 17.

Municipal.

An Exhibit of Municipal Ownership in the United States. (13) Apr. 10.
Improvements in Tests of Macadam Materials. (14) Apr. 19.
Comparison of Brick Tests and Street Wear. Charles Carroll Brown, M. Am. Soc. C. E. (60) May.

Railroad.

Some Principles of Railway Regulation. H. T. Newcomb. (65) Mar.
The Value of Up-to-date Tools for Railroad Work. M. K. Barnum. (61) Mar.
Western Railway Club: Report of the Committee on Revision of the Rules of Interchange. (61) Mar.
The Transition Spiral. Wm. M. Torrance. (4) Apr.
British, Belgian and American Locomotives in Egypt. (12) Serial beginning Apr. 4.
Railroad Organization. Arthur Hale. (15) Apr. 11.
American Locomotive Construction.* (12) Serial beginning Apr. 11.
Tandem Compound Locomotive for Chicago Great Western.* (40) Apr. 11.
The Collinwood Shops of the Lake Shore.* (40) Apr. 11.
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Vauclain Four-Cylinder Balanced Compound Locomotive.* (47) Apr. 12.
A Locomotive for Burning Lignite Fuel. (13) Apr. 17.
Suggestion for a More Uniform Practice in Fixing the Lengths of Spiral Curves. W. D. Taylor, M. Am. Soc. C. E. (13) Apr. 17.
Microscopic Observations on Deterioration in Steel Rails.* Thomas Andrews. (11) Apr. 18.
A Four-Cylinder Compound for Fast Trains.* (15) April 18.
Forty-ton Steel Frame Box Car, Norfolk & Western Railway.* (15) Apr. 18.
The McCann Spreader Car.* (18) Apr. 19.
The Hurley Track-Laying Machine.* L. A. Wells. (13) Apr. 24.
New Types of Freight Locomotives on the Atchison, Topeka & Santa Fé and Northern Pacific Rys.* (13) Apr. 24.
Railroad Water Supply.* William Archer. (40) Apr. 25.
Track Elevation in Newark, New Jersey. Clarence H. Baily. (15) Apr. 25.
The Atlantic Avenue Improvements of the Long Island Railroad.* (15) Apr. 25.
Consolidation Freight Locomotive—Norfolk & Western Railway.* (15) April 25.
Daly's Train-Resistance Computer.* (15) Apr. 25.
Improved Devices for Refrigerator Cars.* (18) Apr. 26.
Elasticity in Draft Gear. R. A. Parke. (Paper read before the Ry. Club of Pittsburg.) (18) Apr. 26.
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PAPERS AND DISCUSSIONS.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE MAINTENANCE OF ASPHALT STREETS.

By JAMES N. HAZLEHURST, M. Am. Soc. C. E.

TO BE PRESENTED SEPTEMBER 17TH, 1902.

Since the impetus given to improved road making, through the genius of Macadam and Telford, nothing has quickened the interest or added more to satisfactory results in highway construction than the introduction of natural bituminous concrete or asphalt as a surfacing material. Appearing as a practical utility simultaneously in Berlin and in Washington, about 1876, its remarkable popularity is attested by a bulletin issued by the United States Department of Labor in 1900, reporting 30 203 946 sq. yds. of asphalt laid in 129 cities in this country having populations of 30 000 inhabitants. When it is recollected that this represents an outlay of approximately $75 000 000, in initial cost and expended during the last 25 years, the enormous proportions of this industry are apparent.

Notwithstanding the great popularity of this class of pavement, both in this country and abroad, its introduction has been attended with many expensive and disastrous failures, as a reason for which, E. Kuichling, M. Am. Soc. C. E., in a recent article, cites the following:

"It may also be mentioned that rock asphalt for street paving purposes was first introduced in Paris in 1854, and that its advantages

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

were promptly recognized by Baron Hausmann, Napoleon III's famous Minister of Public Works. Not only did it afford the means of securing a handsome, sanitary and comparatively noiseless pavement, but its continuity and difficulty of removal made it of little use for the formation of barricades by the turbulent element of the population, and thus contributed greatly to the preservation of law and order by the municipal authorities. Its use in most of the principal streets and avenues soon followed, but with the increased demand came competition and numerous attempts to reduce the cost by the substitution of inferior materials and methods, until finally the quality became so poor as to lead to early disintegration. This result became generally noticeable in Paris about 1880, and in consequence of the inability of the contractors to make proper repairs, asphalt pavements fell into serious disrepute.

"In relation thereto, M. Leon Malo, the well-known French paving expert, and director of the rock asphalt mines at Seyssel, which are controlled by the General Asphalt Company of France, states that up to 1876, all the asphalt pavements of Paris were built and maintained by said company under contract, and gave entire satisfaction. In that year, however, the contracts expired, and the municipal authorities yielded to the pressure brought by rival paving corporations to open the work of construction and maintenance to general competition, and award the contracts to the lowest bidder. The consequence was that the work was taken at low prices by inexperienced firms, and performed improperly, as mentioned above. In the course of five years over 240 000 sq. yds. of the inferior asphalt pavement crumbled, and the contractors went into bankruptcy, leaving repairs of enormous extent undone and creating widespread prejudice against this kind of pavement. The authorities then realized that such work could not be done in a haphazard manner, and thereafter gave contracts only to the most experienced and responsible firms, under strict inspection, and limiting the source of the bituminous rock to a few quarries of established reputation."

The experience of the French capital is not an isolated case, many cities on both sides of the Atlantic having successively faced and decided, each for itself, the advisability of restricted competition or untried materials.

In engineering works, "what is wanted" is generally so clearly understood that there is no difficulty either in readily specifying or exactly following the requirements. The strength, durability and composition of the great mass of materials entering into constructive engineering works have, for the most part, been long and well understood, and their exact values determined experimentally and prac-

tically under a wide range of conditions and tests, but to this rule there are certain notable exceptions, where materials are used singly or in combination with others for certain important work, but where the individual character and resulting combination is made without sufficient scientific knowledge to make certain prediction of successful use.

Such a material is bitumen, the essential base of all asphalt pavements. Bitumen, in mineralogy, is defined as "a hydrocarbon mixture, of mineral occurrence, whether solid, liquid or gaseous," and, in line with this, the Supreme Court of the United States has ruled that natural gas is a true bitumen; other chemists and mineralogists are inclined to include "any and all hydrocarbons, whether natural or artificial, provided they be soluble in carbon bisulphide; hence, in specifications where the percentage of bitumen is a ruling consideration, either natural gas or coal-tar would be equally suitable for the production of an asphalt pavement.

Asphalt is a hard, natural bitumen, and is found in Nature in great deposits such as the pitch lake at Trinidad, or impregnating both lime and sand rock. Not only does uncertainty exist in the classification of bitumens, but, in analytical chemistry and physical test, the differentiation of asphalt and coal-tar is most uncertain. To the chemist, the diamond and the lump of coal are both carbon, while coal-tar and natural asphalt are bitumens, almost impossible to determine, the one from the other, except by the smell.

The wearing surface of the asphalt street should be a true concrete, in which sand is the aggregate, while carbonate of lime dust and the asphalt form the matrix. As with hydraulic concrete, it is important that all voids in the mass be filled, and that asphalt, the cementing ingredient, shall be of proper composition and quality, to the end that the concrete thus formed is durable, tenacious and elastic. While all asphalt is bitumen, all bitumen is not suitable for an asphalt pavement; it may be too brittle or may lack the requisite cementing properties, in which case the pavement necessarily disintegrates and fails. Again, even with the best of materials, the composition may be spoiled in the making, too much of the limestone dust making the pavement hard and brittle, while too great a quantity of asphalt cement will make a soft and yielding surface, in summer, sometimes being so soft as to mire teams, in either case making a renewal of the wearing sur-

face of the pavement a necessity; so that it would seem that the surest way of securing satisfactory results and determining the merits of an asphalt pavement is to give it a trial, requiring considerable time, and to award the execution of the work to experienced asphalt contractors and road builders.

In view of the negative value of tests, except that of long experience, the only specifications likely to produce reliable and exact results, are those which incorporate in their requirements formulas and methods adapted to materials which have previously been used successfully, as made evident by from fifteen to twenty years of steady use under ordinary street traffic; but even the adoption of such well-tried and successful materials and methods is not a positive guarantee of the merit of the asphalt proposed to be laid, for careless manipulation and unaccustomed climatic conditions may make an inferior pavement of materials which have been used successfully elsewhere, while restricting competition to those materials the fitness of which has been established by long use necessarily reduces competition, offering inducement to collusion, combination and fraud; besides, there is lost the possibility of introducing through experiment a material superior to any so far presented for service.

Such considerations suggest the necessity for the broadest competition, and the free exercise of this principle by municipalities is most commendable and, in general, is certainly the true public policy. However, it is equally true that the taxpayer should be at all times protected against the possibility of expensive failure, where inferior or untried materials and methods are permitted to compete upon the same basis with those which from long experience have fully demonstrated their fitness for particular use; and it is obvious that the safe course, under such conditions, is to insist that the burden of responsibility and the cost of full and free experiment be placed where it properly belongs, upon the promoter of the new material.

Were it not for a legal obstacle, to be hereinafter discussed, it would be a simple solution of the difficulty to require a solvent bond for performance and a long period of maintenance.

Unfortunately, any long-term guarantee is likely to be subject to sharp and repeated attacks before legal tribunals, with every chance of having assessments defeated or declared invalid because of the incorporation, in paving contracts, of a clause requiring the con-

tractor to guarantee and keep in repair, for a long-term period, the work executed by him.

The contention has frequently been sustained by the highest courts of the land that such a requirement, unless clearly set forth and intended by the act providing for paving assessments, works an unexpected hardship upon the abutting property owner, who is not only compelled to pay for all or a proportion of the cost of paving in front of his property, but is charged besides with the maintenance of the street in good order for a definite period of years under the so-called "guarantee" clause of the contract, which is, in fact, only a maintenance charge in disguise; an expense which should clearly be assessed against the taxpayer at large, responsible for the proper care and repair of all streets and public places, there being no sanction in the statute or act for putting this expense upon the property owner.

The Supreme Court of the State of Louisiana, on May 29th, 1899, handed down a far-reaching decision, which, in part, held that:

"The maintenance clause in the contract, by which plaintiff company binds itself to keep the street in good order and condition for a term of five years, must be construed with reference to the specifications for the work, and the bid of the plaintiff thereon."

The latter contained the guarantee:

"That the work would be constructed in such manner that the same would endure without requiring repairs for five years, but that, if repairs should become necessary, plaintiff company would make same at its expense. It thus appears that plaintiff's undertaking was to lay paving consisting of such materials, and put down in such manner, as to endure for five years without repair, and it guaranteed its work to be of such character. If not of such character, the loss would fall on the company, at whose expense the repairing needed within five years would be done. This clause is not legally objectionable. It is regarded as simply a guarantee of the quality of the work contracted to be done, and does not render the contract void, as increasing the burden of abutting property owners by requiring them to pay for keeping the pavement in repair for the period of five years after its completion. It is an incident of the contract, not an independent undertaking."

There must be some point, however, where such an obligation for maintenance does become an "independent undertaking," and that point is conceived to be that period of time within which the well-laid asphalt pavement should continue without requiring repairs incident to the wear of ordinary traffic.

A consideration of the department reports of some of the larger cities shows that in the great majority of cases the maintenance of asphalt pavements is provided for by the contractor under the "guarantee" clause for a period of about five years, hence the impossibility of obtaining from the records an approximation of the cost of providing for necessary repairs during such time, but, from reliable authority, it seems certain that the contractor never anticipates the necessity of repair of asphalt pavements, except for accidental cause, during a five-year term; hence that period might properly represent that specific time when maintenance becomes more than "an incident" of the contract cost of paving.

Referring to the experience of Paris, it would appear that about the same period was required before inferior pavements disintegrated to a point necessitating removal; hence it is questionable whether that period of time taken to represent a reasonable guarantee is sufficient to test fully the life expectancy of the asphalt pavement. If this contention is accepted as true, the wisdom of the German municipalities is unquestioned. Their contract requirements for asphalt pavements being that the new pavement shall be kept in perfect repair for a period of nineteen years, beginning on April 1st of the year following the completion of the work. During the first four years the contractor receives no compensation whatever for necessary repairs, but for the remaining term of fifteen years he is paid at the rate of 10 cents per square yard for the entire area under contract.

While the practice in the United States is to omit altogether any provision for long-term guarantees by the original contractor for asphalt pavements, in a few instances, subsequent and supplemental contracts for such repairs have been entered into by municipalities, and include periods ranging from five to ten years in addition to the time of the original guarantee.

The City of Omaha, Neb., has made such a contract, for ten years, at the rate of 8 cents per square yard per annum; Denver pays 10 cents per square yard for a like arrangement, while Cincinnati, subdividing the term into two periods of five years, has contracted for the repair of its asphalt pavements at 7½ cents for the first five years and 14 cents per square yard for the last five years, in all, fifteen years of guarantee or maintenance.

Under the European system, providing for the maintenance of

asphalt streets at a fixed sum per square yard per year, such bonus, payable annually, depends only upon the extent of the area under contract and not upon its legitimate and natural repairs, the effect being that the contractor receives a sum for repairs whether he earns it or not, the sum paid representing the premium upon an insurance policy rather than an expenditure for a real necessity.

The practice of a few American cities, in providing for the maintenance of streets by subsequent additional and supplemental contracts, not necessarily with the original contractor or for identical material, might be so amended as to provide that the first contractor should continue to keep his work in repair, with materials previously used, the payment for which being based upon original prices, and due only where there is a real demand for repairs and a consequent outlay.

From the department reports of Washington and Buffalo, the cost of repairs and maintenance was guaranteed by the contractors for five years. The subsequent expense to each city is averaged as follows:

WASHINGTON.

First period of five years....	0 cents per square yard per year.			
Second " "	29	"	"	"
Third " "	73	"	"	"

BUFFALO.

First period of five years....	0 cents per square yard per year.			
Second " " "	6	"	"	"
Third " " "	48	"	"	"

Accepting the figures showing the cost of maintaining pavements in Washington as a basis, and rounding them out to 3 cents and 8 cents, respectively, and accepting the logical consequence of the preceding argument, it would seem perfectly possible and proper to draft specifications so as to permit open and broad competition, under a sufficient and proper guarantee, and in such manner as to comply with the rulings of the Courts in the matter of maintenance, by stipulating that the contractor should lay the pavement at a price to be agreed upon and to be assessed against the responsible parties under the act providing for pavement assessments, but requiring the contractor to provide a solvent bond, not only for performance, but

for the maintenance of the work in good condition for a term of years, and for compensation which, from the record of other cities, might seem proper and reasonable. The cost of maintenance, thus determined and agreed upon in advance, should be paid annually, only when earned, to the contractor, out of the general city funds, for all legitimate repairs, and at the price previously agreed upon, but any excess of cost, greater than that which the record of other cities has shown to be a proper and just amount of repair work for well-laid asphalt pavement, should be assessed against and paid for by the original contractor.

For the reason that neither the chemist, mineralogist nor engineer can specify with certainty the character, amount or composition of an asphalt pavement, and as results and not precise methods are sought, it would seem reasonable to relieve the contractor of specific limitations while requiring that the entire responsibility for the success or failure of the pavement be borne by him, through stipulation with security that the particular pavement shall last as long and require as few repairs as other well-laid asphalt pavements; and that the reasonable cost of legitimate and necessary repairs should be paid annually, after five years, to the contractor, by the city at large; while any sum expended in excess for necessary repairs should be a charge against the contractor.

In line with the preceding argument, the writer drafted for the Department of Public Works, of Mobile, Ala., a set of specifications from which the following is taken:

Specifications for Asphalt Pavements.

"*Wearing Surface.*—Upon a concrete foundation, or 'binder course,' previously prepared, there shall be laid a wearing surface of asphaltic concrete, composed of natural bitumen, silicon and carbonate of lime, of such proportions and composition, and mixed according to such formula, as may be recommended by the contractor, who shall furnish, with his proposal, the chemical analysis of the asphalt to be used on the work; also, a statement of the ingredients and proportions thereof, and the method of mixing and laying. This material shall be spread and rolled to a finished depth or thickness of not less than $1\frac{1}{2}$ ins., where a binder course is used, and not less than 2 ins. where such course is omitted, and in such manner and by such means as the contractor may deem expedient or likely to produce the best results.

"Concrete made of asphaltic cement and clean gravel may be used to form the binder course; its thickness shall be considered as part of the depth specified for cement concrete, and will be paid for as such.

"For a period of fifteen years, immediately following the acceptance of the work contemplated under these specifications, the cost of maintaining the pavement in good condition shall be guaranteed by the contractor, not to exceed the following rate for each square yard of pavement for the following periods:

"For the first five years, cost per yard for each year...... 0 cents.

"For the second five years, cost per yard for each year... 3 "

"For the third five years, cost per yard for each year.... 8 "

"The maintenance of the pavement in good condition during the guarantee period contemplates, and is intended to provide only for, repairs which may be necessary by reason of defects in the wearing surface of the pavement, made apparent by conditions of weather and traffic. Noticeable irregularities of the wearing surface; cracks exceeding ½ in., and apparent disintegration, all extending over more than 1 sq. ft. of surface, shall be considered cause and necessity for repair, which shall be made and estimated as follows:

"*Guaranteed Annual Cost of Maintenance of Pavements.*—After a pavement has been laid and accepted, and the cost of maintenance guaranteed, at any time during the term of such guarantee, when, in the opinion of the Board of Public Works, and in accordance with the foregoing requirements as to maintenance, the necessity exists for repairing any portion of the pavement, upon notice from the Board, and within fifteen days thereafter, the contractor shall take up, relay or repair such portion of the pavement as may have been designated, and shall repair or relay the same with materials and according to methods prescribed for the original work, and to the satisfaction and acceptance of the Board of Public Works.

"For the purpose of estimating the value of such repair work, in addition to the contract price per yard as established by the original bid, there shall be allowed an extra amount for such repairs, as follows:

For each separate amount, as ordered, less than 20 yds., 20 per cent.

For each separate amount, as ordered, more than 20 and less than 50 yds., 15 per cent.

For each separate amount, as ordered, in excess of 50 yds., 10 per cent.

"Should the cost of repairs, as estimated above, exceed in any one year the sum for which the contractor has guaranteed that such pavement could be maintained, any additional work, ordered by the Board of Public Works, shall be done by the contractor, under the terms of the specifications, and without cost to the city.

"If, in the opinion of the Board of Public Works, there should arise the necessity for removing, repairing and replacing any section of the pavement for the laying of water, gas or other mains, or for the repair of the same, or for any purpose whatsoever, upon the written order of the President of the Board of Public Works, the pavement shall be opened, replaced or repaired by the contractor, in the manner and under the terms provided for repair work, but the cost of such work shall not be charged to the contractor, or considered as a part of his guarantee."

Under the provisions of the foregoing specifications and the penalty expressed in a bond in the sum of \$15 000, contractors for asphalt paving have recently undertaken some 17 000 sq. yds. in the City of Mobile, Ala., for the following prices:

A.—Construction of 6-in. concrete foundations, including grading 65 cents per square yard.
B.—Paving with asphalt..........\$1.15 " "

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

A BRIEF HISTORY OF ROAD CONDITIONS AND LEGISLATION IN CALIFORNIA.

Discussion.*

By Messrs. James Owen and George W. Tillson.

Mr. Owen. James Owen, M. Am. Soc. C. E.—This paper is hardly in the line of a professional topic. It recites the history and conditions of road promotion and road legislation in the State of California, and is very interesting, as it gives the experience through which the State of California has gone, which is, to a large extent, similar to that of other States in the Union, except that in California work is not as far advanced as in the Eastern States.

One of the burdens of Mr. Manson's subject is the cry that many engineers make, viz., the interjection of the political element into road work.

Attention should be called particularly to the clause on page 92,† because the speaker has never before seen it in the shape of a legal enactment. If it were in active practice in this section of the United States it would devolve upon the engineer to determine whether a bid was too high, and if it should turn out that the work cost more than he estimated, he would have to pay the difference out of his own pocket. It is a question whether the engineering profession at large would like to have such a practice incorporated in their ethics.

* This discussion (of the paper by Marsden Manson, M. Am. Soc. C. E., printed in *Proceedings*, for February, 1902), is printed in *Proceedings*, in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to June 27th, 1902, will be published subsequently.

† *Proceedings*, Am. Soc. C. E., February, 1902.

There is one point about the California work that does not seem to be stated by Mr. Manson, and that is, that the State Penitentiary, in the early incipiency of the road work of that state, put up a large stone-cracking plant, and at that time a very advantageous rate was made with the Southern Pacific Railroad to haul the road material to different sections of the state. The state engineer at that time told the speaker that they were hauling road material at a very moderate cost for a distance of over 600 miles. The speaker does not know whether or not that practice is kept up now, but it was a very important procedure. The railroads there felt that highway construction was an adjunct to their business, and offered these inducements to facilitate the further development of road work. The railroads in the East, so far, have not taken that view of the road work, but have always demanded full rates for their mileage, in common with other fields of enterprise. Mr. Owen.

There is another interesting phase of Californian legislation which differs materially from the practice in the East, and it has a great deal of merit: The law provides that a sum of one-half the road tax shall be reserved for what is called a "good-roads fund," out of which the cost of the road construction is paid. After the road is built it is turned over to the state for maintenance, and the state, under the statute, must provide and appropriate $100 000, or so much thereof as may be necessary, for the purpose of carrying out the provisions of that act. The practice in the East is entirely different. Where the states have interjected their authority and funds for the construction of a road, the provision afterward is that the local authorities shall pay for the maintenance—that is, as far as the speaker knows—he does not remember exactly the practice now in Massachusetts—whether or not the State Road Commission there provides a fund for the maintenance—but in New York, New Jersey, and the States with which he is cognizant, the local authorities have complete charge of the expenditure for maintenance.

The speaker is inclined to think that that Californian provision is an improvement. The more concentrated the authority of maintenance the better will be the result. The difficulty always found in road construction or road maintenance is, that while people are very anxious to have good roads, and appreciate them, the local authorities are not anxious to appropriate the necessary moneys to keep them in good repair.

George W. Tillson, M. Am. Soc. C. E.—In Toronto, Canada, the practice in receiving bids is somewhat similar to that mentioned in the last clause of the California law. When bids are asked for in Toronto, or rather when they are received, the practice is for the city engineer himself to put in a bid on the work. If that bid is lower than any of the others received, the work is awarded to him and he completes Mr. Tillson.

Mr. Tillson. it by day's labor. The object, of course, is not to give the city engineer the opportunity to pay for anything out of his own pocket, but is to prevent the bidders from making a combination and getting more than a reasonable price for the work, because it ought not to be difficult for the contractors to do work at a fair profit, but for less than city officials, in this country, at least, could do it by day's labor.

In looking over the report of the city engineer, where he has reported upon work for which he put in his proposal and was awarded the work, it is found that, as a general rule, he has often done the work for less than the amount of his bid, but in some few cases the cost of the work has exceeded his bid.

In regard to the Massachusetts law, the President of the Commission told the speaker, a short time ago, that at the present time they have charge of the maintenance of the roads, although at first they did not; and that the cost last year averaged $95 per mile for maintenance, over all the roads, although some of the roads, on which the work was done by contract, were kept in good repair for $70 per mile.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

IS IT UNPROFESSIONAL FOR AN ENGINEER TO BE A PATENTEE?

Discussion.*

By Messrs. S. Whinery and James Owen.

S. Whinery, M. Am. Soc. C. E.—The question propounded in the title of this paper is one upon which there exists a radical difference of opinion in the engineering profession, particularly among civil engineers. It is a question of importance, from more than one point of view, and, therefore, it merits careful consideration. Mr. Whinery.

It is desirable that a rational conclusion should be reached and generally accepted by the profession and the public. The paper, therefore, is timely and pertinent, and should be discussed fully and candidly.

It will hardly be claimed, except by those who argue that the whole theory of patents is wrong, that the engineer is debarred by either law, morality or professional ethics from taking out a patent under any circumstances. No valid reason can exist for denying him the right to patent inventions that have no conceivable connection with, or no relation to, his profession.

Using an illustration referred to by the author: If an engineer invents a novel egg-beater, he may, if he chooses, apply for and accept a patent on his invention, and dispose of it for a consideration, with-

* This discussion (of the paper by A. R. Eldridge, M. Am. Soc. C. E., printed in *Proceedings* for February, 1902), is printed in *Proceedings*, in order that the views expressed may be brought before all members of the Society for further discussion.

Communications on this subject received prior to June 27th, 1902, will be printed subsequently.

Mr. Whinery. out violating accepted moral principles, or transgressing the strictest canons of professional ethics. This much may be accepted without discussion. The only question, then, at issue is, may the engineer patent inventions which relate directly or indirectly to the profession, or to his professional work, without violating either the law, the accepted moral code, or the ethics of the profession?

It will be conceded that the public at large neither has nor can have any peculiar legal or moral claim upon a man because of his vocation or profession; every citizen owes certain obligations to his fellow-men and to organized society, and he may pay a part of these obligations in the particular kind of current funds that he may be best able to supply. Thus the physician may contribute to the general good his assistance and advice on questions of public health; the lawyer, his help in framing public laws, and the engineer may contribute so much of his special knowledge as the public is entitled to, in designing schemes for public improvement. But how much is the public entitled to? Somewhere there must exist a line beyond which contributions to the public good must become benevolence, rather than duty. The public has a right to demand that which is duty, but not that which is benevolence. In the way of monetary or property contribution, the duty of the citizen is discharged when he pays his taxes, and the public has no right to demand or ask more.

There are but few who deny that inventions are personal property—the property of the inventor—and a patent is merely a certificate of ownership issued by the authority of the government. The public has no more claim upon the personal property of the inventor than upon the chattels or lands of other citizens; therefore, we may exclude the general public from this discussion. There are, then, left to be considered, the rights of but three parties or interests: The profession, the client of the inventing engineer, and the engineer himself.

What claim has the profession upon the inventions of its individual members?

It cannot be held that the profession has any legal right to the personal property of its members; nor can it be claimed that the member is bound by any moral obligation to contribute his property to the profession. But, outside the pale of the law and the moral code, it is recognized that the profession has claims upon its members which are not less real because they are somewhat difficult to define. They are embraced in the general term "Professional Ethics."

In the first place, the member has a material personal interest in supporting and advancing the character and standing of the profession before the public, because his own standing in the eyes of the public is affected thereby. From the material point of view, the higher the services of the civil engineer are rated, the more remunerative will be the work of the individual engineer.

Another and a higher motive is found in the fact that the character and dignity of the profession is, to a certain extent, reflected upon its individual members. Personal interest, therefore, dictates that the individual shall render such services as he may be able to the elevation of the profession at large. A higher and still more worthy motive impels the individual to feel a pride in and be loyal to the highest interests of the profession, for the good of the profession itself, and to extend to his fellow-members the most refined courtesy and loyal assistance in all proper ways. This may be accepted as a sound general statement, but difficulty arises when we attempt to define just how far an engineer is called upon to go, in contributing from his personal property, whether material or intellectual, to the profession or to its individual members. Mr. Whinery.

We may reasonably expect that he will contribute his individual knowledge to the general stock, though he may expect, and we may not debar him from, some professional compensation therefor.

When a valuable paper is read before this Society, the profession and its members are benefited, but the author may properly expect some compensation in the way of increased reputation. If an able book on some branch of engineering is written and published the author benefits the profession, and deserves our warmest thanks, but we do not claim that he should not receive a suitable royalty from the publisher. Other illustrations might be given, but they are unnecessary.

It must be accepted that in the profession, as elsewhere, "the laborer is worthy of his hire," and therefore entitled to it. We may assume that the products of an engineer's brain are as much his personal property as are the products of his hands, and that he is free to make such disposition of both kinds of property, subject to all proper and usual limitations, as in his judgment may be to his best interests.

Inventions relating to or connected with the engineering profession may be divided into two general classes.

First, those that relate to what we may call the engineer's workshop, such as special instruments or labor-saving appliances, for doing work, the scope of which is confined to the personal use of engineers. With regard to these, it may be an open question whether loyalty to the profession, and courtesy to its members does not require that their use be made free to all. In the medical profession it is distinctly held that it is unprofessional to patent inventions of this class. This position would be strengthened if it could be shown that the profession would reap the whole advantage of the inventor's generosity. Unfortunately, this is not always the case. For instance, an engineer may invent a valuable labor-saving instrument. It is made and sold by an instrument-maker, who fixes the price, not at cost and a reasonable profit, but at what he thinks he can get, independent of any royalty the inventor might exact. The result would be increased

Mr. Whinery. profit to the maker or dealer, without any benefit to either the profession or the inventor. Upon the whole, however, the position of the medical profession seems reasonable and proper, and the speaker would favor its adoption by engineers.

To the second class belong those inventions that confer no special benefit upon the profession or its members, but which accrue to the benefit of clients, manufacturers, contractors, or the public at large. As a pertinent illustration we may cite improved methods or processes for dealing with sewage. The practicing engineer may very properly recommend to his clients such improved processes, whether patented or not, if he is convinced that, all things considered, including royalty, their use will result in benefit or economy to the client. But such recommendations, probably, will not add to or detract from the engineer's professional reputation or advantage, nor will it increase the fee he may charge for his services. Consequently, he receives no benefit, nor does the profession, from the use of the process. If benefit results, it accrues wholly to the client or to the public at large.

The engineer, presumably, will not recommend, and the client or the public will not use, the process unless they believe that its use will be advantageous or profitable, and, if advantageous or profitable, they cannot reasonably object to compensating the inventor. As well might they claim that because they can buy an inefficient tool for a certain price, the manufacturer of a more efficient and possibly more expensive one must sell it to them at the same price. Now, unless it can be shown that an inventor has no property right whatever in his invention, it seems preposterous to say that he is not entitled to, and may not justly collect, a fair compensation for its use. And since such use is not for the benefit of the profession or its members, it cannot alter the conclusion if the inventor happens to be an engineer. Much more might be said on this branch of the subject, but it seems unnecessary.

The fact that persons calling themselves engineers, whether legitimately or not, may have attempted to foist upon the public so-called inventions that have no real value, or may have claimed the invention and ownership of processes or devices that are not patentable, because of lack of novelty or because of prior invention, and may have harrassed engineers or their clients therewith, is no argument against the soundness of the conclusion at which we have arrived.

There seems to be an impression among many that, in the medical profession, it is considered unprofessional to take out patents of any kind. This is not the case. The ban is placed only upon patents for professional instruments and devices, and upon medicines and methods of treatment. The argument against patents for medicines and methods of treatment is based largely upon the consideration that

they are primarily for the benefit of the sick and suffering, and that ordinary benevolence would render it unseemly to prevent their freest use, or to place a tax upon human suffering. No such argument applies to the great majority of industrial inventions, which are the special field of the engineer, and the cases are therefore clearly differentiated. Mr. Whinery.

Coming now to the second class of parties interested, what claim has the client upon the inventions of the engineer?

Two classes of cases must be considered. First, those in which the investigations of the engineer have led to important inventions while in the client's employ, and relating to the client's business; and second, those in which the engineer may find it to the client's advantage to make use of inventions perfected by him before he entered the client's service, and quite independent of the client's business.

In cases of the first class the legal status of the two parties is well settled and clearly understood. It may be stated briefly thus: If A is an employee, say a mechanic in the business or shop of B, and invents an improved device or process relating to the business of B, A may take out a patent covering his invention. B will be entitled to make full and free use of the invention in his own business or shop, but will have no other claim upon it, and A may sell the patent in whole or in part, subject, of course, to B's right of use, as stated previously, to any other persons, not excepting the business competitor of B. Time does not permit taking up the arguments for and against the soundness of this legal dictum. Its universal acceptance by the courts, in this country, at least, indicates that it is founded upon right and equity. And as law and morals are practically synonymous, it must be in line with good morals. Unless, therefore, it can be shown that the relation of engineer and client differs from that of employee and employer it must be good law and sound morals for the engineer who may happen to be an inventor; and, as professional ethics is based on the moral law, it must be sound from the ethical point of view.

Cases of the second class are embraced mainly in the first, except that there can be no possible question as to the ownership of the invention. It will scarcely be held that when a client employs an engineer he thereby acquires any right to make use of the engineer's private property, whether that property be his house, or his invention. There is one difference, however, in the two classes of cases which merits notice. The engineer may not recommend the use of his own patented invention to his client without the fullest statement of the facts, including the royalty expected, and even then may not press its use upon his client. Nor may he make use of his invention in work under his charge without the full knowledge or consent of his client, even if no royalty is charged or expected.

The third party in interest is the engineer himself. Upon his

Mr. Whinery. relation to the subject we must content ourselves by touching very briefly.

If neither the profession nor his clients are unjustly or injuriously affected by the fact that the engineer is an inventor and patentee, he has the undoubted right to be his own judge as to whether, being an inventor, he shall, or shall not, take the necessary action to place this intellectual property under the protection of the same law that guarantees to him the exclusive use of his chattels and his lands. If he chooses to avail himself of that protection, and to control and manage that property so as to yield him its full value, he may do so without trespassing on any rights of his fellow citizens and without violating any reasonable code of professional ethics.

There can be no wrong in the engineer holding, using, or disposing of property honestly and honorably acquired. Whether that property is the result of physical or mental effort does not matter, and the possession of the one should no more subject the owner to reproach or professional discredit than the possession of the other.

There is another aspect of the matter, which, while it has no relation to morals or to professional ethics, deserves consideration. Assuming that the inventor might be actuated by pure benevolence in working out and perfecting valuable inventions for the sole benefit of the public, his object might be defeated if he declined or neglected to take out a patent.

To develop and introduce an important invention requires usually the expenditure of a large amount of money. The inventor is not often able to supply this money himself. He must seek the aid of capitalists. They will not supply the necessary means unless assured that what they invest will be returned with liberal profit. They must have some assurance that, after they have spent large sums for the development and introduction of the invention, they will be able to prevent competitors from robbing them of the reward for their labor and expenditure. This can only be accomplished through patenting the invention. Without the protection of a patent they would not supply the necessary money, and the invention, however valuable it might be to the public, would not be made available for its use. Without the protection of a patent the inventor of the railway air-brake could not have obtained the capital to develop, introduce and secure its general adoption at so early a period, if at all, and probably, even now, it would not be in general use. That its rapid introduction and use has been of incalculable value to the public, as well as to the railroads, no one will deny. Thus, the patenting of inventions is indirectly beneficial to the public, and if the inventor reaps a liberal share of the benefit, no one can justly complain.

The writer believes that the time has come when the profession should take positive and unmistakable action on this question of the

right of the engineer, not only to invent, but to protect his invention in the way the law has provided. Mr. Whinery.

Such action is due to the profession, which should not be placed in the anomalous position of being divided against itself. It is due to the individual engineer, who is entitled to know what the profession regards as professional or unprofessional. It is due to the engineer's clients and to the public, in order that they may know what to expect when dealing with engineers who may be also inventors.

JAMES OWEN, M. Am. Soc. C. E.—This paper is full of good thoughts and ideas upon the subject of the breach of professional ethics occasioned by a civil engineer acquiring a patent, and, while it is really intended as an *ex parte* argument in favor of such a practice, a careful analysis of the author's statements evinces a tendency somewhat contradictory to his assertions. Mr. Owen.

The great complaint of the civil engineer in the past, and to a more limited degree at present, is the lack of appreciation, by the community at large, of the status and abilities of the professional engineer, and it is easy to realize such a condition when engineers of the author's standing fail to appreciate it for themselves.

The whole point at issue is a proper definition of the word profession, and to determine accurately what is a professional obligation in civil engineering is a very difficult problem. In the legal and medical professions, tradition and legal enactments have fairly crystalized practice, so that the ethical codes of these professions are well defined, and transgressions of such codes are rare, and when made are accompanied with proper and defined penalties.

In the kindred profession to civil engineering, *viz.*, architecture, the subject of ethics has been a matter of consideration for a long time, and the speaker believes that a satisfactory professional status for architects has been defined, but years will elapse before it is fully and unanimously accepted.

Taking the architect as basis for argument, it may be clearly appreciated that any one designing and also constructing a building is not acting in a professional capacity, even though it may take more brains and energy than merely to make the plans and superintend the construction. Applying this creed to engineering, any engineer who departs from a line of practice in which he is delivering to his client more than his own thoughts and ideas is departing from legitimate and professional practice; for these thoughts and ideas must and should be untrammeled by any question of individual interest of the engineer himself, and the resultant, whether delivered by letter or drawings, belongs to his client.

The first problem to be adjudicated in this controversy, and more pertinent probably than any other point, is: Is it of advantage to the engineer to be a professional man, and is it also of advantage to the country at large?

Mr. Owen. So much of the world's progress of to-day is dependent upon the free thought and careful study by engineers generally that it may be urged that by limiting an engineer's line of action to a comparatively small sphere good results may not ensue, and the pre-eminence achieved by engineers here, under such conditions, may be easily lost.

Looking carefully over the field of civil engineering, with its varying ramifications, it can hardly be said that such a result can be feared, as it shows that, as time goes on, the purely professional practice is gaining greatly on the so-called merchantable practice.

Take bridge construction: In years gone by, the engineer, in most cases, designed and erected the structure. To-day, the best and most costly structures of that class are being designed by purely professional engineers. In pumping machinery, so long considered a purely manufacturing industry, the designs of professional engineers have shown better results in economy and duty. In railroad construction, to-day, the engineering is purely professional; and in water and sewerage works, by far the larger proportion is constructed on professional lines. Thus it will be seen that there will be a very small limitation by the engineer confining himself to purely professional lines, and if such limitation is in any case individually harmful or irksome, there is no prohibition to any man acting in other lines, except that his work will not be professional.

It has been said that the crystalized practice of any engineering field becomes in time a trade, but it may be said also that a systematic trade does not require the services of a professional engineer.

Given these general outlines of professional engineering, the inference can be drawn that it is professionally wrong for an engineer to acquire an interest in any patent. If he acquires a patent and uses it there is certainly no moral delinquency, but it lowers the dignity of the profession, and lowers its appreciation by the public at large, and it is gratifying to note the public disapproval based on a report of a controversy which has arisen in a large city where a professional engineer has attempted to force the use of a patented article on construction work over which he has control.

In conclusion, the speaker desires to endorse almost all the remarks in Mr. Eldridge's paper, and is satisfied that, if their application be made on purely professional lines, there will be no divergency of opinion.

Vol. XXVIII. MAY, 1902. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEEES.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

LINE AND SURFACE FOR RAILWAY CURVES.

Discussion.*

By Charles C. Wentworth, M. Am. Soc. C. E.

Charles C. Wentworth, M. Am. Soc. C. E. (by letter).—Mr. Geddes mentions favorably a feature of the proposed method of relieving circular curves: That, generally, it does a minimum of violence to the original location. This is due to the length of the center line being unchanged. Mr. Wentworth.

There is another feature due to the same cause: That such revisions, when applied to a preliminary location, will result in a line that will almost invariably fit the ground better than the original simple circular curves. This is true whether the original line be one seeking low ground over a point or high ground in a ravine: The departure from the original circular curve is in the right direction at its P. C., middle, and P. T.

Still, as Mr. Geddes seems to doubt the desirability of such a treatment of circular curves, a few words on its practical application, and the advantage to be derived therefrom, may not be out of place.

On one hand there is what may be called current practice. Given, a circular curve, with its tangent, staked out on the ground (as every curve must be at some period of its existence), this given center line is not followed when the track is being put in final condition for the passage of the trains, but the points of curve and tangent are shifted from one to ten rail lengths in order to introduce that necessary easement which may be called the "trackman's spiral." Finally, elevation is given the outer rail, by general rule, fully at the point of curve.

* Continued from April, 1902, *Proceedings*. See February, 1902, *Proceedings*, for paper on this subject by Charles C. Wentworth, M. Am. Soc. C. E.

Mr. Wentworth. Which point of curve?—the original one, the final one, as fixed by the trackman, or some intermediate point?

It will be seen, then, that under this procedure the final outcome in a given case cannot be fully foreknown. As a practical example of this, see the discussion by Mr. Boggs* on Mr. Lee's paper on "Transition Curves." Nevertheless, when tempered by judgment and experience, current rules applied to such work do secure a fairly good result; otherwise, so-called circular curves would have been abandoned long ago.

A partial analysis of this result may be made as follows: If a car were to pass quickly from a tangent to circular curve accurately laid to the center line, but without elevation being given to its outer rail at its P. C., the outward lurch, especially at the forward end of the car, would be great. A contrary lurch, of any desired magnitude, can be secured by elevating one rail on straight track. A combination of these two opposing lurches may produce a fairly steady car, much in the same way that two properly superimposed sound waves produce silence. Just how much elevation of the outer rail is required, in any particular case, at the end of the tangent or the beginning of the curve, depends on the essential features of the "trackman's spiral"; but such elevation is generally considerably greater than would be necessary on the main curve, if a well-considered transition spiral had been introduced.

These considerations may be exemplified further by the result attained when the end of a circular curve occurs on a bridge. Here limitations are imposed as to the lateral departure from the projected center line; and the elevation of the outer rail is given, from rules, by the bridge carpenter. Final adjustment by the trackmen being difficult, or impossible, the result is seldom as good as if the rails were on ties and ballast.

On the other hand, there may be a center line staked out consisting of circular curves connected with their tangents by well-proportioned spirals. On laying track there will be no desire on the part of the trackmen to deviate therefrom; as such a center line is what they have striven for, and obtained partially, since railways began. Monuments, then, are even less necessary than before. A certain displacement is avoided, and possible displacements are no more apt to occur, or more injurious if occurring.

If the elevation of the outer rail be thought difficult of proper attainment on spirals, it will be granted that on the middle circular curve, at least, the problem is unchanged. If an elevation of 1 in. per degree be established, then, on the main curve, the middle ordinate to a chord 61.8 ft. long will equal the required elevation. If 2 ins. per degree, the length of the chord is 87.4 ft. For e inches elevation per degree, the length of the chord is $61.8 \sqrt{e}$, in feet.

* *Transactions*, Am. Soc. C. E., Vol. xlvi., p. 396.

Mr. Wentworth.

The elevation per degree of curve being assumed, and the corresponding length of chord known, this same chord will determine the elevation of the outer rail at any point on the spiral. The spiral is readily recognizable by its uniformly increasing ordinate, and, in the space occupied by it, an extra elevation (say ½ in.) is to be provided, for reasons given in the paper; but the elevation assumed for the main curve is nowhere to be exceeded. Even by such a practical treatment of spirals as this, better and more certain results will be attained than by what has been herein (perhaps inadvisedly) called current practice.

In bridge work, or other work wherein the exact position of the center line and elevation of the outer rail are required to be accurately foreknown, the writer's method allows of such determination precisely.

The writer does not agree with Mr. Geddes that what is needed is a short spiral fixed by tables. There is no more reason (apart from the labor) for a uniform spiral than for a uniform degree of curvature for all main curves. Acting on this, it has been the endeavor of the writer to simplify means for a general solution of the problem, whereby the engineer's spiral may be made as long as necessary for the complete development of the "trackman's spiral," aforesaid.

As Mr. Morse says, the maintenance of the low rail at grade, and the elevation of the outer rail, effects the motion of trains. Whether such is sufficiently prejudicial to cause the depression of the inner rail one-half—ordinarily a difficult and expensive performance—may be judged, in any given case, on such lines as the following:

A train weighing 1 000 tons, and moving at a speed of 10 miles per hour, has necessarily stored in it 6 680 000 foot-pounds of energy. If his 2° 30′ curve be taken as an example, with its elevation of 6 ins. in the outer rail only, the energy required to lift the center of gravity of the entire train 3 ins. is 500 000 foot-pounds. The remaining energy assuming that the engine could maintain the speed of 10 miles per hour, save for the resistance due to the manner of elevating the outer rail only, is 6 180 000 foot-pounds, which corresponds to a speed of 9.6 miles per hour.

This reduction of speed is gradual, and is finally accomplished at the time when the caboose at the rear of the train reaches the summit of the elevating grade. In other words, the final reduction, of only $\frac{4}{10}$ mile per hour, is reached just when the obstruction is passed.

The same amount of energy (500 000 foot-pounds) is imparted to the train again on reaching the descending grade at the P. T.; so that the net result of this pair of velocity grades, as they properly are, is zero; and an argument against their use becomes rather one against the somewhat prevalent practice of overtaxing that willing horse, the locomotive engine; considering that the lowering of the inner rail be attended with any difficulty or expense whatever.

Vol. XXVIII. MAY, 1902. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE SUPPORTING POWER OF PILES.

Discussion.*

By Ernest P. Goodrich, Jun. Am. Soc. C. E.

Mr. Goodrich. Ernest P. Goodrich, Jun. Am. Soc. C. E. (by letter).—No pile formula can give more than an approximation to the supporting power of the special pile observed, and only at the time of driving; but, with an intimate knowledge of the soil conditions, a good pile formula becomes of value, and considerable money often can be saved, at the time of driving, through its proper application. This is where the science of pile driving can influence the art.

Of course, it is eminently better to test piles under the actual conditions to be encountered; but this is almost invariably impossible, the few actual tests of even single piles showing this conclusively.

After the accumulation of whatever evidence and experience has come down to us, we seem to be justified in assuming that Sanders' formula, as it is usually known, when applied to penetrations of from ½ to 1 in., comes sufficiently near the truth, with perhaps the need of a slight change in his constant.

Two other formulas, somewhat different in character in that they involve falls of at least two different heights, may be added to the list for reference:

Haagsma: $\dfrac{h - h'}{p - p'} \times \dfrac{W_h}{(W_h + W_p)}$

Morrison: / Kreuter: $\left.\begin{matrix}\\ \\ \end{matrix}\right\} \dfrac{h - h'}{p - p'} \times W_h.$

Haswell: $\}$ constant $\times W_h \sqrt{h}$
McAlpine: $\}$ $30\ [W_h + (0.228 \sqrt{h} - 1)\ 2240].$

* Continued from April, 1902, *Proceedings*. See December, 1901, *Proceedings*, for paper on this subject by Ernest P. Goodrich, Jun. Am. Soc. C. E.

Haswell's formula is based on a penetration of ½ in. only, and hence is hardly comparable with the others in that it does not involve a variable p. In this respect, it is like that of McAlpine, who also has $\sqrt{h}$. Their observations and conclusions, which make the supporting power vary with the square root of the fall, are at variance with the work of the writer and of all other observers. Mr. Goodrich.

TABLE No. 3.—Variations in Supporting Power, from Varying Assumptions.

v'	R_W	Formula.	F for p equals 1.	F for p equals ¼.	F for p equals 4.	Percentage of Error.
0	....	$0.287 \frac{W h}{p}$	156 000	....	....	4.3
2	....	$0.276 \frac{W h}{p}$	149 040	....	....	0.0
5	....	$0.256 \frac{W h}{p}$	138 000	....	....	6.0
10	....	$0.230 \frac{W h}{p}$	124 000	....	....	11
20	....	$0.178 \frac{W h}{p}$	98 500	....	....	37
2	$\frac{1}{2}$	$0.276 \frac{W h}{p}$	149 040	....	....	0.0
2	$\frac{3}{8}$	$0.204 \frac{W h}{p}$	110 160	....	....	26
2	$\frac{1}{4}$	$0.132 \frac{W h}{p}$	71 280	....	....	52
2	....	$3.312 \frac{W H}{p}$	149 040	....	....	0.0
2	....	$3.312 \frac{W H}{p}$	....	596 160	....	0.0
2	....	$3.312 \frac{W H}{p}$	....	....	37 260	0.0
2	....	$10 \frac{W H}{3 p}$	150 000	....	....	0.6
2	....	$10 \frac{W H}{3 p}$	....	600 000	....	0.6
2	....	$10 \frac{W H}{3 p}$	....	....	37 500	0.6
0	....	$\frac{10 W H}{3 p + \frac{1}{10}}$	145 100	....	....	2
0	....	$\frac{10 W H}{3 p + \frac{1}{10}}$	....	529 411	....	11
0	....	$\frac{10 W H}{3 p + \frac{1}{10}}$	....	....	37 190	0.1
0	....	$\frac{3.444 W H}{p + 0.04}$	148 058	....	....	0.6
0	....	$\frac{3.444 W H}{p + 0.04}$	....	534 414	....	10
0	....	$\frac{3.444 W H}{p + 0.04}$	....	....	38 360	3.0

Mr. Goodrich. To show the possibility of wide variation, even with a most carefully prepared formula, for small variation in conditions, Table No. 3 has been prepared. It is believed to be self-explanatory. In computing F, W_h has been taken as 3 000, h as 180, H as 15, p various, v' various and R_W various.

The Annapolis tests, which had entirely escaped the attention of the writer, are of great interest. The actual load and the load computed by the writer's final formula are shown in Table No. 4.

TABLE No. 4.

Number.	Length.	Point.	Butt.	Hammer.	Fall.	Penetration.	Actual load.	Formula: $\frac{10\,W\,H}{3\,p}$	Nature of Soil.
1...	91	7	22	2 300	22	$1\frac{3}{4}$	75 000	96 500	Water, 12 ft.; mud, 60 ft.; sand, 6 ft.
2...	91	7	22	2 300	22	$1\frac{1}{2}$	85 090	112 600	Water, 12 ft.; mud, 60 ft.; sand 12 ft.
3...	73	9	18	2 300	$33\frac{1}{2}$	$3\frac{3}{4}$	34 000	67 000	Water, 12 ft.; mud, 61 ft.
4...	80	12	8	2 300	22	2	38 000	84 500	Sand.
5...	82	13	9	2 300	22	1	110 000	168 666	Sand.

When the actual values of R_W, and properly assumed values of v' are used, much closer computed results are found, but, under ordinary circumstances, such refinements are not practicable.

The peculiar, and apparently erratic, variation in the results can be readily and satisfactorily explained by the soil conditions, but strongly go to prove that a pile formula alone, without other knowledge, is indeed a poor crutch.

The matter of a proper factor of safety is believed to be one which must be settled specially by each engineer, for each piece of work in hand, from known soil conditions and the uses to which the foundation will be put.

It is well to note that a pile will fail by crushing with a load of approximately 6 000 lbs. multiplied by the square of the diameter, in inches; and loads greater than given by this, where found by pile formulas, should be discarded.

A series of experiments somewhat similar to those made by the writer and illustrated in Figs. 2 to 14, was carried out by Mr. J. M. Heppel, in England, some years previous to 1867, but his description* is too meager to afford much information.

The writer begs to acknowledge his appreciation of the kind remarks made by those discussing his work.

* *Minutes of Proceedings*, Inst. C. E., Vol. xxvii, p. 42.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE STIFFENING SYSTEM OF LONG-SPAN SUSPENSION BRIDGES FOR RAILWAY TRAINS.

Discussion.*

By Messrs. L. S. Moisseiff, H. A. La Chicotte and L. L. Buck.

L. S. Moisseiff, Assoc. M. Am. Soc. C. E.—The literature on the subject of suspension bridges which is available for the design of long-span bridges of this type is very meager, especially in the English language. The information given in standard text-books on bridges is either obsolete, in its cultivation of old theories, or, where more modern methods are followed, this information is so scant as to prove of little practical value. The engineer is compelled to review old reports and reprints, many of which contain errors, typographical and original. But, more serious is the notable absence of any numerical data on suspension bridges of spans exceeding 1 000 ft. Mr. Moisseiff.

A suspension bridge, in its action, is such that the effect of moving load, temperature, etc., is generally not represented by linear equations. This means that the stresses do not vary in simple proportion to the applied forces. Hence, approximations and professional guesses are not so easily made. The paper presented by Mr. Mayer, therefore, will be much appreciated by the members of this Society. While chiefly discussing the question of three-hinged *versus* two-hinged stiffening trusses, it gives numerical values and averages for the longest span suspension bridge yet contemplated. Therefore the absence

* This discussion (of the paper by Joseph Mayer, M. Am. Soc. C. E., printed in *Proceedings* for February, 1902), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

Communications on this subject received prior to June 27th, 1902, will be published subsequently.

Mr. Moisseiff. of a systematical tabulation and the lack of explanatory diagrams will be much regretted. The addition of a few sketches and some additional information would greatly relieve the paper of the mysterious air now hovering over it. For instance, the cross-section of the cable is nowhere given, and, while it is not a matter of much difficulty to determine the same, such information should certainly be given. As presented, in order to make some simple comparisons, the reader has to make a diligent search for the data.

While giving the numerical results of a concrete case, the author, in many instances, has failed to give the intermediate steps in their derivation, and, mainly, the assumptions on which they are based. Just comparisons of these results with results otherwise obtained are thereby made impossible. This applies especially to the values given to the deflections under different conditions. The notation used is also unsystematic. American engineers are used to struggling with much wilful notation, and are accustomed to finding in each book different symbols denoting the same thing; still, they will find the author's notation of horizontal wind pressures per linear foot, as x and y, somewhat out of the usual.

In finding the "Stresses Produced by the Change in Length of the Cables in Suspended Stiffening Trusses of Three Hinges," the author uses the formulas deduced by him in *Engineering News*. These formulas are approximate only, as stated by himself.

It used to be an axiom, in the treatment of three-hinged arches and suspension bridges, that stresses due to changes of temperature, elongation of cables and displacement of the points of support, did not affect the stresses in these structures. Their deformations were considered to be insignificant, and their apparent statical determinateness eliminated all elastic equations. This was true within certain limits, namely, when the spans were short, and the trusses stiff enough to make the deformations, due to the above causes, so small as to be negligible, thus approaching the statical assumption of rigidity. But the long-span suspension bridge, with its comparatively flexible stiffening truss, does not generally come within these limits. Stresses due to elongations of cables will be caused in three-hinged as well as in two-hinged trusses.

In the report of the "Board of Engineer Officers as to Maximum Span Practicable for Suspension Bridges," G. Lindenthal, M. Am. Soc. C. E., gives the first analytic treatment of the subject of "Temperature Strains in Three-Hinged Arches." After stating that the old theory of freedom from temperature stresses is erroneous, he continues:

"There are, of course, no temperature strains in the middle hinge, but they do exist for any change from the normal temperature in the arches between the end and middle hinges, and are too large to be neglected in the computations."

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This, of course, would also be true for any elongation of the cables. In the succeeding proof of the foregoing statement, Mr. Lindenthal assumes that the new curve of the deflected bridge will also be parabolic, and it follows that "the maximum bending moment at the middle half-girder is as large as in the middle of the continuous girders."

Professor Joseph Melan, the well-known authority on suspension bridges, has also taken up the subject.* After stating that a rigid treatment of the problem may be made, but is difficult and cumbersome, Professor Melan approaches the subject by also assuming the new line of equilibrium to be a continuous parabola. Assuming the neutral axis to bend in a parabolic curve, it follows that the maximum temperature stress at the center of the half-span of the three-hinged bridge is 80% of the maximum bending moment of the end-hinged stiffening truss. Professor Melan states that these stresses are actually excessive, "as the cable does not remain parabolic, but, due to the unequal distribution of suspender stresses, it forms a kink at the center."

Mr. Mayer, in his analysis in *Engineering News*, on which the computation of temperature stresses is based, starts with another assumption: He assumes the trusses to remain rigid and to turn around their end hinges. With the assumption of rigid trusses it is also tacitly assumed that the distribution of the load on the suspenders remains as before. The cable curves, therefore, will remain parabolic in their two halves, and will have a kink at the center. On this assumption the author's formula is based.

It will be noticed that the two different assumptions made in the analysis, and which lead to entirely different conclusions as to the importance of elongation stresses in three-hinged stiffening trusses, form the two extreme conditions of the case. The assumption of the deflected cable remaining one continuous curve will necessarily give higher values, as Professor Melan anticipates. The other assumption of the rigid truss will give values which are too low. The actual case will lie between these extreme assumptions. The truss, of course, will not be rigid, but will deflect and thereby change the curve of the cables from the presupposed parabolic form. The new curve of the cables will be a resultant curve intermediate between the parabola of the original curve and the neutral line of the deflected trusses. The new curve, in general, will consist of two catenarian halves, the tangents of which, at the center of the span, form an oblique angle; but, as the truss increases in stiffness, then more nearly will the new curve approach the two parabolic halves having a kink at the center.

In the following the writer will endeavor to establish the general equation of this curve. The general reasoning followed is analogous

* *Zeitschrift des Oesterr. Ing. u. Arch. Vereins*, No. 36, 1900.

Mr. Moisseiff. to that used by Professor Melan, in determining the true curve of continuous end-hinged stiffening trusses, in his work on "Suspension Bridges and Arches;" its application to the three-hinged truss is original with the writer.

The bridge is supposed to be free from all temperature and elongation stresses at a normal temperature and under the fixed load only. It is also supposed that then the curve of the cable is parabolic. Both assumptions are actually verified in practice.

Let H_f = the horizontal pull in the cables at the normal state under fixed load only;

S_0 = the stress in the suspenders, per linear foot;

K = the weight of the cable, per horizontal foot.

Then the differential equation of the equilibrium polygon will be

$$H_f \frac{d^2 y}{d x^2} = -(S_0 + K) \quad \text{(1)}$$

When an additional load, q, per linear foot, comes on the bridge, or any other change takes place, the suspender stress changes to S_1, the horizontal pull to $(H_f + H)$, and the ordinate of the equilibrium polygon to $y + \eta$. These new quantities are again subject to the equation of condition.

$$-(H_f + H) \frac{d^2 (y + \eta)}{d x^2} = S_1 + K \quad \text{(2)}$$

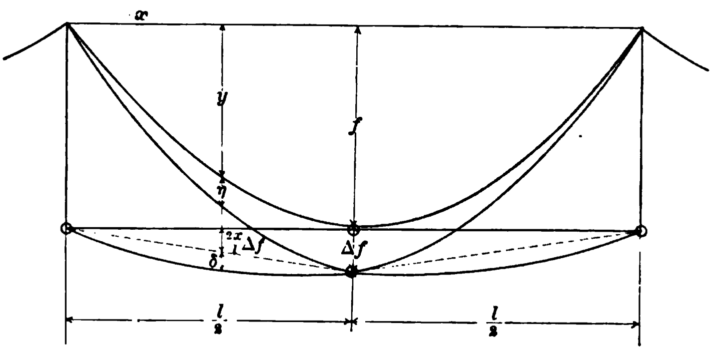

FIG. 17.

η represents the deflection of the cable at any point x (Fig. 17). Meantime, the half trusses have also been deflected. If we neglect the very small elongation of the suspenders due to the change, the deflection of the cable, $\eta = \delta + \frac{2x}{l} \Delta f$. δ represents here the deflection of the truss due to bending, and Δf the deflection of the cables at the center hinge. The expression, $\frac{2x}{l} \Delta f$, represents the deflection

of the truss due to its turning on its end hinge, as can be seen from the diagram. Mr. Moisseiff.

According to the common theory of flexure, $-EI\frac{d^2\delta}{dx^2}=M$, where $I=$ moment of inertia, $E=$ coefficient of elasticity, and M the bending moment. Since the load per unit of length is the second differential quotient of the bending moment,

$$EI\frac{d^4\delta}{dx^4}=q-[s_1-s_0]\dots\dots\dots\dots\dots\dots(3)$$

The addition of the foregoing three equations gives:

$$EI\frac{d^4\delta}{dx^4}-(H_f+H)\frac{d^2\delta}{dx^2}-H\frac{d^2y}{dx^2}=q\dots\dots(4)$$

Writing for brevity, $\frac{H_f+H}{EI}=c^2\dots\dots\dots\dots\dots\dots(5)$

and assuming I and q to be constant, within the limits of the integration, the differential equation (4) is integrated by the aid of a particular solution,

$$\frac{d^2\delta}{dx^2}=A\,e^{cx}+B\,e^{-cx}-\frac{H}{H_f+H}\left(\frac{q}{H}+\frac{d^2y}{dx^2}+\frac{1}{c^2}\frac{d^4y}{dx^4}+\dots\dots\right)$$

due to the original parabolic form $\frac{d^2y}{dx^2}=-\frac{8f}{l^2}$ and $\frac{d^4y}{dx^4}=0$,

then $$\frac{d^2\delta}{dx^2}=A\,e^{cx}+B\,e^{-cx}-\frac{H}{H_f+H}\left(\frac{q}{H}-\frac{8f}{l^2}\right)\dots\dots(6)$$

The forces, $q-(s_1-s_0)$, acting on the trusses through the suspenders cause a moment

$$M=M_0-\left(H_f+H\right)\left(\delta+\frac{2x}{l}\Delta f\right)-Hy\dots\dots(7)$$

where M_0 represents the moment which the same load would produce in a simple supported beam of the same span, l.

$$\frac{d^2\delta}{dx^2}=-\frac{M}{EI}=c^2\eta-\frac{c^2}{H_f+H}(M_0-Hy)\dots\dots(8)$$

The comparison of equalities in Equations 6 and 8, and the introduction of $y=\frac{4f}{l^2}x(l-x)$, results in

$$\delta+\frac{2x}{l}\Delta f=\frac{H}{H_f+H}\times$$

$$\left[C_1e^{cx}+C_2e^{-cx}+\frac{8f}{c^2l^2}-\frac{4f}{l^2}x(l-x)+\frac{M_0}{H}-\frac{q}{Hc^2}\right]\dots\dots(9)$$

C_1 and C_2 are constants, being, respectively, $\frac{AEI}{H}$ and $\frac{BEI}{H}$.

The values of C_1 and C_2 are determined in the usual way.

For $x=0$, $\delta=0$; for $x=\frac{l}{2}$, $\delta=0$. This gives two new equations,

$$C_1+C_2+\frac{8f}{c^2l^2}-\frac{q}{Hc^2}=0,$$

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$$C_1 e^{\frac{cl}{2}} + C_2 e^{-\frac{cl}{2}} + \frac{8f}{c^2 l^2} - \frac{q}{H c^2} + \frac{q l^2}{8 H} - f - \Delta f \frac{H_t + H}{H} = 0,$$

writing

$$F = \frac{q l^2}{8 H} - f - \Delta f \frac{H_t + H}{H}.$$

Wherefrom, we obtain,

$$C_1 = \left[\frac{H + H_t}{H} + \frac{F}{1 - e^{-\frac{cl}{2}}} - \frac{8f}{c^2 l^2} + \frac{q}{H c^2} \right] \frac{1 - e^{-\frac{cl}{2}}}{e^{\frac{cl}{2}} - e^{-\frac{cl}{2}}} \quad \text{........} (10)$$

$$C_2 = - C_1 - \frac{8f}{c^2 l^2} + \frac{q}{H c^2} \quad \text{........} (11)$$

The greatest deflection of each half span will be found at the quarter point, $x = \frac{l}{4}$,

$$\text{Max. } \delta = \frac{H}{H_t + H} \times$$

$$\left[C_1 e^{\frac{cl}{4}} + C_{2e}^{-\frac{cl}{4}} + \frac{8f}{C^2 l^2} - \frac{q}{H c^2} + \frac{3}{4} \left(\frac{q l^2}{8 H} - f \right) \right] - \frac{\Delta f}{2} \quad \text{......} (12)$$

The catenary character of the deflection curve is seen at once from the equations.

In the case of a span of 1 433 ft., a versed sine of 156 ft., stiffening trusses 35 ft., center to center of chords, and ratio of moving load to fixed load = 1 to 3.5, the numerical evaluation of the foregoing formulas showed a deflection at the middle of the half-span trusses equal to 10% of the deflection at the center hinge. The greatest moment in the center-hinged stiffening truss, due to the elongation of the cables, proved to be about 40% of the greatest moment of the end-hinged truss. As the equations show, these moments are also depending on the ratio of moving to fixed load in the bridge and on the stiffness of the trusses. As it might have been expected, the true equilibrium curve of the cables will lie between the two extreme assumptions made in the approximate analysis; so are also the stresses induced by the deflection between the two extreme values.

The author finds a deflection of his bridge at the center, under full load and maximum change of temperature, of ± 6.9 ft. He then determines the stress which would be caused by this deflection in continuous end-hinged stiffening trusses of 60 ft. and 140 ft. depth, respectively. This comparison is erroneous. A continuous truss, under the same conditions, will deflect less than one with a center hinge. While the center-hinged truss will not carry much load to the

abutments as a truss, the one without a center hinge will, in some cases, carry considerable load. The cables will be relieved by the amount carried by the trusses, and, as a result, their deflection will be less. Mr. Moisseiff.

Using the author's notation and assumptions, the load carried by the end-hinged truss is given by the following:

The greatest moment, due to the load, p, per linear foot, carried by the trusses, is $M = \frac{p\,l^2}{8}$. The constant stress per square inch in the truss assumed by the author will then be $t = \frac{M}{d\,A} = \frac{p\,l^2}{8\,d\,A}$, where $A =$ the area of each chord.

The author deduces: $t = \frac{4\,e\,\delta\,d}{l^2} = \frac{p\,l^2}{8\,d\,A}$; hence the load per linear foot carried by the truss, $= p = \frac{32\,d^2\,e\,A}{l^4}\,\delta$.

For a depth of truss, $d = 60$ ft., and an average area, as given by the author, $A = 727$ sq. ins.; the load carried by trusses results in $p =$ 565 lbs. per linear foot. This represents 6.7% of the total moving load.

For a depth, $d = 140$ ft., and the same section, $p = 3\,080$ lbs., or 36% of the moving load.

The cables will be relieved by the above amount, and their elongation due to moving load will be proportionately less. For the 140-ft. truss, the deflection will be reduced by 1.15 ft., or about 17% of the total deflection assumed.

It would also appear that the pointed shape which the cables assume after the deflection of the center-hinged truss should, by its mere geometric shape, everything else being equal, give a deflection in excess of the deflection of a curve continuous over the center. It would not be surprising should it be found that the increased deflection of the three-hinged truss is quite a considerable percentage of the deflection of the continuous curve.

The whole argument of the paper is based on the deduced deflections and stresses due to the elongation of the cables by moving load and temperature. With a change in their values, the whole comparison of the relative economy in material is thrown out. It would appear, therefore, that computations nearer to the actual conditions should be made before conclusions as to the relative economy of three-hinged and two-hinged trusses are drawn.

The author states that "three-hinged, deep, stiffening trusses have the advantage that the maximum grade is only one-half of that which occurs if there are fewer than three hinges." This would appear to be of determining importance. If a three-hinged truss should really have one-half the maximum grade of the end-hinged truss, this fact would decide the case, for all long-span railroad bridges, against the two-hinged truss. Fortunately, such is not the case.

Mr. Moisseiff. For the sake of general comparison, the grade will be expressed as an algebraic formula. It will also be assumed that the deflection is the same in all cases, which, as shown, is not true. For a three-hinged truss with rigid stiffening trusses, the grade is constant up to the center, and is given by tan. $\alpha = \frac{2\,\eta}{l}$. Fig. 18.

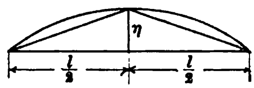

FIG. 18.

For a continuous truss, hinged at the ends, the following cases may be considered : If the bending of the truss is assumed to be parabolic, the maximum grade at the towers is tan. $\alpha = \frac{4\,\eta}{l}$. The grade, following the law of the parabola, will decrease to zero at the center. If the neutral curve is assumed to be circular, the same is a very close approximation. This is the author's assumption. It means that the truss, under full temperature and moving load, is a beam of constant stress at any point of its span.

For a beam of constant moment of inertia, the bending will follow the common neutral curve. According to the common theory of flexure, $M = E\,I\,\frac{d^2\eta}{d\,x^2}$, hence, tan. $\alpha_x = \frac{d\,\eta}{d\,x} = \int \frac{M}{E\,I}\,d\,x$, integrated between the limits of x, which makes tan. $\alpha_x = 0$ and tan. $\alpha_x =$ tan. α_x. For a full uniform load, $M = \frac{p}{2}\,x\,(l - x)$. This gives

$$\text{tan. } \alpha_x = \frac{d\,\eta}{d\,x} = \frac{p}{2\,E\,I}\left[\frac{l\,x^2}{2} - \frac{x^3}{3}\right]_{\frac{l}{2}}^{0} = \frac{p\,l^3}{24\,E\,I}.$$

The deflection of the same beam at the center under the uniform load, p, is, as is well known, $\eta = \frac{5\,p\,l^4}{384\,E\,I} = \frac{5\,l}{16} \times \frac{p\,l^3}{24\,E\,I} = \frac{5\,l}{16}$ tan. α.

Hence, tan. $\alpha = 3.2\,\frac{\eta}{l}$.

Now, the distribution of greatest moments due to combined moving load and elongation, in well proportioned two-hinged stiffening trusses, is such that the section of the chords is almost constant for the middle half. The conditions causing the maximum grade are due to uniform, or almost uniform, distribution of load on the truss. The sections of the chords are determined, not by this loading, but by partial moving load. The truss, therefore, evidently, will never be in the condition of constant stress assumed by the author. It will be much nearer to the assumption of a constant average moment of inertia.

Actual computations on the deflection of a two-hinged truss, of 1 433 ft. span and 35 ft. depth, show that a correction of about 6% of the deflection would bring the result to the same as for an average

constant moment of inertia throughout. The grade at the towers will then be tan. $\alpha = \frac{3\,\eta}{l}$. Mr. Moisseiff.

As was found from the true deflection curve deduced previously, well proportioned stiffening trusses of the three-hinged type will deflect at the quarter points about 10% of the deflection at the center, or $\frac{\eta}{10}$. Supposing the assumption of circular bending to be true for center-hinged trusses, the greatest additional grade due to this deflection becomes $\frac{0.8\,\eta}{l}$. The total maximum grade of the three-hinged truss thus becomes $\frac{2.8\,\eta}{l}$, as compared to $\frac{3\,\eta}{l}$ of the two-hinged truss. The difference in grade between the two systems, then, is not 100%, but about 7%.

If the corrections of deflection discussed in the previous part of this discussion are made, the above small difference in grade will completely vanish, and it will probably appear that a three-hinged will have a steeper grade than a two-hinged truss. Really, it should not have needed so many figures to arrive at this conclusion.

Of course, all this discussion of the maximum grade is somewhat academical. The condition of extreme cold and no load on a span of such length will seldom, if ever, be realized. But the writer believes that such a sweeping statement as to grade as that made by the author should be contradicted, as it conveys an erroneous notion.

The obvious result of the introduction of a center hinge is the throwing of more of the moving load on the cables. The same is true for the wind system. In a comparison of the relative economy of the two systems discussed, the effect of this addition on the cables should be considered. The writer has failed to see in the paper any mention of the additional load on the cables, and its effect, if any, on their section and increased weight.

The effect of the backstays in increasing the deflection of the main span shows some interesting features. Based on the figures given by the author, it will be easily found that, at mean temperature and with a fixed load, only the versed sine of the backstay of the long span of 1 740 ft. will be 29.8 ft. With the application of a moving load covering the whole span, the above backstay will have an upward deflection of 8.5 ft. This, of course, has a great influence in making up the deflection of the main span. The question then arises as to whether or not the introduction of a properly designed side-span stiffening truss, hung from the cables, would give better results, under the conditions of the case.

H. A. La Chicotte, M. Am. Soc. C. E.—The subject of suspension bridges has not received the same attention from engineers as Mr. La Chicotte.

Mr. La Chicotte would be expected from the great advancement which has taken place in recent years in other branches of engineering construction. It is scarcely two decades since the development of American bridges approached present standards, and in this time but one suspension bridge of first importance has been constructed in this country. The demand for this construction has been limited by the rare conditions which warrant its adoption; and, consequently, it is not strange that this subject has been comparatively neglected, and that its literature should be meager and widely scattered. The author's contribution, therefore, is of interest and value to American engineers, as containing much information on this rather abstruse subject not hitherto readily accessible.

It is to be regretted, however, that the author has not made his discussion more general, and made freer use of diagrams and sketches to illustrate his meaning more clearly, inasmuch as the text of the paper is often obscure or ambiguous.

In making such free use of data pertaining to the proposed North River Bridge, and, in fact, basing his discussion of the subject on a special design for that particular location, there is a tendency to limit discussion and direct attention outside the lines suggested by the author. At the outset of the paper the features chosen for special attention are the proper number of hinges to be used in the stiffening truss, and the proper depth of the truss. None of the questions raised on these points has been answered directly, although a certain depth was assumed for each style of construction; but nothing is given to show that such assumptions are proper, or that some other depth of truss might not have given better results. In a general discussion it is not so much a matter of importance that a three-hinged truss 140 ft. deep be cheaper than a two-hinged truss 60 ft. deep, or than cable bracing 50 ft. deep; but rather that the foregoing depths are proper in each case, and why. The author has, no doubt, fully investigated this branch of the subject, and will give it in some detail in the final discussion.

Because of the large amount of labor involved in a technical discussion of this kind, it is hardly to be expected that engineers will do more than engage in what might be termed a negative discussion; that is, where the author's arguments are not convincing, or even when direct issue is taken therewith, a mere statement to that effect should be sufficient without adducing contrary proof.

One of the chief points made by the author in favor of the three-hinged truss is that of maximum grade, this being for the three-hinged truss only half of that found for the two-hinged truss. This is a matter of great importance in a bridge to be used for railroad traffic.

The author's comparison is hardly fair, because he uses the same deflection at the center of the main span for both designs. Under the

influence of live load and temperature, the cable deflects quite uniformly in the case of the two-hinged truss, while, with the three-hinged truss, the cable forms a kink at the center of the main span under the restraining action of the two half-trusses. The reaction of the trusses at the center hinge pulls the cable lower than in the other case, thereby increasing the deflection materially for the same load and temperature, and consequently increasing the grade. Approximate computations, based upon the author's assumptions, show this increased deflection of the three-hinged truss to be 46% greater than that of the two-hinged truss for the same load and temperature. Mr. La Chicotte

More accurate calculations, based upon proper assumptions, will show a real difference somewhat less than that given above.

The effect is to increase the grade of the three-hinged truss above the value given by the author.

Again, the author's assumption of uniform unit stress throughout the chords of two-hinged trusses cannot be realized in practice. The moment of inertia of the trusses will be nearly constant over the middle half of the span, decreasing toward the end supports, but not so fast as the moments due to temperature and load. The elastic curve in such case will lie intermediate between those for beams of uniform strength and of uniform section. In practice, therefore, the two-hinged truss will not bend in the form of a circle, and the grade will be less than given by the author. The net result is that, under the same conditions of load and temperature, there is a slight advantage in the ratio of about 7 to 8, in favor of the three-hinged truss.

For finding the stresses produced by the change of length of the cables in suspended stiffening trusses of three-hinged trusses, the author gives the formula:

$$T = \frac{\delta_1 (w + q) L^2}{h\, l^2}$$

where T = the load per linear foot of truss induced by a deflection δ_1;

L = span of cables, from center to center of towers;

l = " " trusses, " " " " " supports;

w = weight of cables per linear foot of bridge;

q = pull of suspenders " " "

h = versed sine of the cable.

If, for simplicity, the span of the cable and the truss be the same, or $L = l$, and as $(w + q)$ = the dead load of the bridge, the foregoing formula may be written:

$$T = \frac{\delta_1}{h} (\text{dead load}).$$

That is, the load, T, which is simply a portion of the dead load picked up by the trusses during deflection, is quite independent of the length of span or moment of inertia of the truss, and depends

Mr. LaChicotte only on the total dead load of the bridge and the ratio of deflection to the original versed sine, or dip of the cable.

If $\delta_1 = h$, the truss would carry the whole uniformly distributed dead load except the weight of the cable, and the cable would carry its own weight and the reaction of the trusses at the center hinge. Under these conditions the cables would assume the position of tangents to their original curve, but they are prevented from so doing by their own weight, and because their length is not sufficient to permit it.

The formula is not correct in form, but may give approximate results for comparatively small deflections.

Again, in the application of this formula, exception may be taken to the author's statement that:

"In three-hinged stiffening trusses those stresses which are due to the lengthening of the cables from moving load are of opposite sign to the maximum moving-load stresses occurring at the same time; their neglect is therefore on the safe side, giving maximum stresses considerably too large."

This statement is apt to be misleading, and this instance serves to emphasize the danger of basing a general argument on a specific case involving special conditions and assumptions.

The formula previously given denotes the load imposed on the trusses by a deflection, δ_1, due to elongation of the cables. There is no reason for discriminating between the elongation due to temperature and that due to live load, except as to amount; in other words, it matters not how the elongation of the cable is produced, it will cause deflection, and the latter will induce stress in the trusses. The positive and negative moments are not necessarily coincident or equal, as the maximum position may be produced by a short load more or less concentrated, while the maximum negative moment in one half-span is generally produced by a load covering nearly all of the other half-span. Broadly speaking, however, the maximum positive and negative moments of the two half-trusses are about equal and occur simultaneously, when the load nearly covers one half-truss.

Under this condition, a rise of temperature increases the positive moment and decreases the negative, while a fall of temperature has the contrary effect. The effect of temperature on the moments is due to a change of length of the cables, and any cause which produces a change of length of cable will affect correspondingly the moments in the trusses.

If the supports of the trusses are adjusted so that the latter are free from stress at mean temperature, the maximum stresses in the trusses are due to partial live load only, and are equal and opposite.

If the temperature rises or falls, and produces positive or negative stresses in the trusses, these stresses are to be added algebraically to those produced by live load, in order to obtain the maxima. Therefore, at a low temperature, the maximum or total negative stresses

will be larger than the positive, and *vice versa.* Since any elongation of the cables produces positive stress in the trusses, it is necessary, in order that the maximum positive and negative stress be equal, that the neutral condition of the truss be assumed at such temperature and loading that the total upward and downward deflection of the truss, under combined temperature and live load, be equal. Mr. LaChicotte

The correctness of the author's statement, quoted previously, depends entirely upon the assumed temperature and loading at which the trusses are neutral or not stressed.

If such assumptions give greater negative than positive stresses, the statement is correct; as any elongation of the cables, whether from temperature or live load, reduces the negative moments or stresses in the trusses; but it likewise increases the positive moments, and therefore, for the neutral condition of the trusses, that condition of load and temperature should be chosen which will make the maximum positive and negative moments, under these combined influences, equal, and the smallest possible.

Another statement, in which the author has not made himself clear, is the following:

"The stresses in the chords of three-hinged stiffening trusses produced by changes in the length of the cables vary with change in the depth of these trusses in the same ratio as the stresses due to an unequally distributed moving load. The chord sections must vary nearly as the sum of these stresses. The former stresses per square inch of chord section, therefore, are nearly the same, whatever the depth of the three-hinged trusses."

It is quite evident that the author does not convey the meaning he intended, but there is also some doubt as to what that meaning really is. Why temperature stresses should vary with the depth of truss "in the same ratio" as live-load stresses, is not easily apparent. Upon the author's assumption that the two half-trusses remain practically straight for all positions of the cables—a condition approximately realized only with very deep trusses—the chord stress will vary directly as the depth of truss in the same manner (not ratio) as the stresses due to live load. This being so, the next statement of the author follows naturally, viz., "the chord sections must vary nearly as the sum of these stresses," but it must be added that the chord sections vary inversely as the depth of the truss. It does not follow, however, that "the former (temperature) stresses per square inch of section, therefore, are nearly the same, whatever the depth of the three-hinged trusses." Such may be the fact, but the arguments leading up to this conclusion are far from convincing.

It is true that the deeper the truss, the greater the moment tending to produce distortion, but this moment depends upon the rigidity, rather than upon the depth, of the truss. It is impossible, however, that the temperature stress per square inch of chord section should

Mr. LaChicotte vary directly as the depth and at the same time be "nearly the same, whatever the depth of the three-hinged trusses."

The author's statements, as quoted herein, are too sweeping, and, while he may find some justification for them in the special design with which he deals, in the speaker's opinion, they will not be found capable of general application.

Mr. Buck. L. L. Buck, M. Am. Soc. C. E.—In reference to the question of stiffening trusses: When the speaker rebuilt the suspended structure of the Niagara Railroad Suspension Bridge, the moving loads per foot passing over it were about 1 200 to 1 400 lbs., and the trains were hauled by a medium-weight shunting engine. The structure had to be erected without interrupting traffic over the bridge, and, consequently, it was necessary to give the trusses about the same depth as the old ones.

The speaker would have liked to decrease the depth somewhat, but that was out of the question. The greater the flexibility of the truss the less the stress upon its members. This flexibility would ordinarily be obtained by giving the truss a depth that would allow that flexibility with given unit stresses. With the depth as required, it was necessary to obtain the flexibility by slacking off the truss rods, as each truss rod was provided with a turnbuckle having right and left hand threads. By first bringing the turnbuckles up to a bearing, and then turning the turnbuckle back about half a turn, it gave ⅛ in. of slack, which afforded the flexibility required.

Some years after, during August, when the temperature was about maximum, the foreman noticed that these rods were slack, and, thinking that they ought to be drawn up tight, went to work and screwed them all up. They had formerly been adjusted at mean temperature, in which case the temperature would produce no stress on the members at that temperature, and as the whole change or deflection between the extremes of temperature was 2 ft., of course the truss would only have to bend 1 ft. each way from the mean; but tightening up these truss rods during the hottest weather required a bending of 2 ft., enormously increasing the temperature stresses. At the same time, the loads per foot had more than doubled. One cold morning in the winter, when the upper chord had a very heavy tensile stress upon it from temperature, a heavy coal-train, of ten cars, with the heaviest loads on each car, ran out on the bridge from the New York end, and produced a very heavy stress on the upper chord at one-third the distance from the other end, and the chord broke. The train went on across the bridge, and merely closed up the break, and it was fully as capable of resisting a compressive stress as ever.

The speaker cannot quite agree with Mr. Hildenbrand's suggestion that the stiffening structure is not important in the suspension bridge, but thinks it is of vital importance. In the first place, with excessive

deflections, the motion is very disagreeable to passengers riding over Mr. Buck the bridge, and, with such excessive undulations, the cables and other members would rapidly wear out.

There is another question as to the depth of the stiffening truss that is not very often considered, and that is the amount of versed sine of the cable. If the versed sine is large, the truss can be deeper than if the versed sine is smaller, in proportion to the span. With the larger versed sine there is not so much vertical change in the cable between extremes of temperature.

A steel tower has the effect of decreasing the amount of deflection between the extremes of temperature, as when the cables lift up, the tower is shortened somewhat—about 1 in. in 100 ft.—and *vice versa*, thus decreasing the change.

Vol. XXVIII. MAY, 1902. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

THE BOHIO DAM.

Discussion.*

By Messrs. J. L. CAMPBELL, J. T. FORD and GEORGE S. MORISON.

Mr. Campbell. J. L. CAMPBELL, M. Am. Soc. C. E. (by letter).—In 1896 the writer had occasion to carry an irrigation canal across the Rio Grande, in southern New Mexico. This canal is 34 ft. wide on the bottom, and is designed to carry 5 ft. of water. The river at the point of crossing, in the apex of a sharp bend, is 300 ft. wide and was carrying about 500 ft. per second during the low-water season, when this work was done. The entire Rio Grande Valley has a fertile alluvial soil, from 2 to 6 ft. thick, underlaid throughout by a deep bed of fine sand, thoroughly saturated to within about 10 ft. of the surface. The river channel is composed of fine sand and quicksand, with some fine gravel, all taking a slope of 4 or 5 horizontal to 1 vertical when saturated.

The elevation of the grade line did not admit of an overhead crossing, and the canal was taken under the river-bed in four wooden pipe lines, each 50 ins. inside diameter. The tops of the pipes were placed from 3 to 7 ft. below the bottom of the channel, between five parallel rows of piling, cut off and capped over the pipes below the bed of the river. All this necessitated an open excavation across the river, 400 ft. long., 25 ft. wide on the bottom, and having an average depth of 10 ft. To do this, a temporary channel for the river was first cut across the neck of land formed back of the crossing by the bend in the river, after which a dam of sand bags was thrown across the

* Discussion continued from April, 1902, *Proceedings*. See January, 1902, *Proceedings*, for paper on this subject by George S. Morison, M. Am. Soc. C. E.

channel parallel to and immediately above the site for the crossing, and made tight by dumping sand on the upper side. This forced the water through the temporary channel, and the excavation for the pipe lines began. This was accomplished as an open excavation by the use of "slip" scrapers, the sand being deposited against the dam above and also formed into a dam across the channel below to prevent overflow from back-water, as the river rose. Mr. Campbell.

When the excavation was completed, the side slopes had flattened of their own accord to 1 on 4, due to the saturation of the fine round sand. The water in the river stood against the upper dam 15 ft. above the bottom of the excavation, and 10 ft. above against the dam on the lower side.

The water was kept out of this excavation, which had a filtering area of approximately 40 000 sq. ft., under an average head of 12.5 ft., by two vertical centrifugal pumps, one a No. 8, and the other a No. 6. The No. 8 pump could easily keep the pit clear of water when running at its normal capacity of 400 cu. ft. per minute. Taking the filtering area of the pit at 40 000 sq. ft., and the mean effective head of water at 6.25 ft., the velocity of inflow, in feet per second, for the 90-ft. head on the Bohio Dam is as follows:

$$\frac{400 \times 90}{40\,000 \times 6.25 \times 60} = 0.0024 \text{ ft.}$$

As evidence that the maximum capacity of the No. 8 pump was greater than the inflow, there was an interruption of the pumping for a day, after which the pump succeeded in emptying the pit and keeping it empty, the No. 6 pump being out of service.

In making calculations for a large storage reservoir in the bed and valley of the Rio Grande, the writer has assumed that any loss of water due to filtering into the bed and sides of the reservoir would steadily decrease, due to the filling of the voids in any sand-bed by the fine silt carried by the river settling and being forced into the sand by the heavy pressure.

New irrigating ditches in the sandy soil of this valley lose much water when first put into service, but soon become comparatively water-tight by a coating of silt deposited by the water. At the end of an irrigating season, a ditch with a light grade will have 3 or 4 ins. of pure sediment covering its perimeter. The writer has observed that it requires several hours for water to soak through 6 or 8 ins. of this fine clay silt after it has been thoroughly dried, and that percolation through wet strata of it in the river channel is inappreciable.

If the Chagres carries as much silt as the Rio Grande (from descriptions of the former the writer concludes that in this respect both rivers are quite similar), the silting of the reservoir behind the Bohio Dam would certainly tend to a decrease of the percolation of water through all reasonably fine sand and gravel beds.

Mr. Campbell. A tight row of sheet-piling, 40 or 50 ft. deep, under the dam, would make the filtering slow and difficult. The conditions of a filter-bed specially prepared to pass water at given rates are more favorable, and will give a higher rate, than the indiscriminate mixtures forming the structure of alluvial valleys. Proof of this is found in the fact that even filter-beds rapidly become clogged, and require constant cleaning.

Mr. Ford. J. T. Ford, Esq.* (by letter).—It is obvious that the dam proposed by Mr. Morison is, *per se*, superior in stability to the dam proposed by the Commission, not only because of its greater mass, shorter distance across the valley between abutments, and form of construction, which assures homogeneity throughout and extraordinary cheapness, but also because the masonry core-wall, especially that part of it which comes above the present natural ground line, in the Commission's plan, divides the whole structure into two disconnected wedges of earth, subject to possible different degrees of subsidence on opposite sides—the upper part of the core-wall may possibly crack under unequal pressures—and, if reliance is placed mainly on that core-wall for tightness, the results may possibly be disappointing, from a variety of causes, and, under extreme conditions, the danger point may even be reached long before such conditions could affect or even threaten the safety of Mr. Morison's dam.

The writer proposes a masonry apron-wall of peculiar construction, absolutely sealing the geological valley at about the site of Section *C*, *i. e.*, the French dam site, the narrowest point of the valley, and extending only up to the natural ground level, not into the structure of the dam at all, but simply as an additional or complementary feature of the

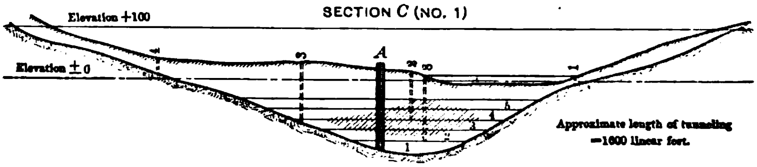

Fig. 16.

first-class structure proposed by Mr. Morison. See Fig. 16, the cross-section of the valley (No. 1) at *C*, and the cross-section of the author's dam—*VXYZ* (No. 2). The method here proposed for constructing this apron-wall is entirely novel, as far as the writer knows. A good working shaft is sunk at *A*, Fig. 16, at any desirable distance up the bank and away from the edge of the water at normal river level; this shaft should go down to bed-rock, and its upper end, above ground, should be suitably protected, if necessary, from extraordinary flood levels. A tunnel (No. 1) is then started at the bottom of the shaft in both direc-

* M. Inst. C. E.

tions in the alignment of the proposed dam, of suitable dimensions Mr. Ford. and timbered in the ordinary way, the bed-rock being followed and effectually sealed as the basis for the first tunnel floor. If the seepage is great the excavation can be filled as soon as timbered in comparatively short sections, or, if too much seepage exists for pumping, it is possible to use the freezing process for driving the tunnel, or even the extreme necessity of an air-lock carried forward at the end of the tunnel would in such a position still give advantages over the present pneumatic methods, for cheap handling of material to be removed, boulders, etc., and, most important of all, an absolutely perfect sealing of the bed-rock. The gallery along the center of the tunnel would be left with such dimensions as would permit of effective handling of the material in and out to the shaft, pipes for the pumping and ventilation, etc., and, when completed, the galleries, if desired, could be filled with solid concrete, but it would seem to the writer a very great advantage indeed to leave the galleries open for permanent inspection of the work at all times. The jointing of the successive sections of such a tunnel would not be either smooth or perpendicular, but preferably be left with their natural slopes, after complete ramming, to receive the filling for the next section, which would thus give a continuous and satisfactory line of hollow wall, perfectly tight, both in its bed joints and section joints; it would also be desirable to leave sufficient space, below the roof timbering of the tunnel and above the concrete, for the proper ramming and depositing of the material.

Tunnel No. 2 would then be started from Shaft *A*, the roof timbering of Tunnel No. 1 being removed and the top of Tunnel No. 1 replacing the bed-rock as the floor for Tunnel No. 2, and so on, in succession, until such height is reached, or such conditions found as to seepage, etc., when it might be more convenient, or cheaper, to break ground at the top, with caisson and ordinary pneumatic work, and sheet-piling in the ordinary way, to carry the wall up to the original ground surface. Thus the most expensive and difficult part of the core-wall would be built under water without disturbing the overlying strata or letting in the water at all, and without assuming any risks of flood or other damage during the protracted periods of early construction. The valley would be sealed with a perfect and continuous wall, instead of a series of semi-detached masonry columns; or, to express it in other words, a wall with horizontal bed-joints would be built, instead of the so-far unprecedented vertical bed-joints proposed in the Commission's plan. The result would be a wall capable of inspection at any and all times during and after construction.

Few words need now be said as to the cost. The problem is simply the construction of 1 600 linear feet of tunnel, only differing from any ordinary railway tunnel in that the hole through the middle is smaller and that successive sections of the tunnel are on top of each other

Mr. Ford. instead of being continuous from the end. What, then, will be the cost of 1 600 ft. of such tunnel, under the conditions described as obtaining at Bohio? The writer ventures to assert that he would make money on the contract at an average cost of $250 per linear foot. Thus the cost of 1 600 ft. would be about $400 000. Assuming that price to be doubled, and made $500 per linear foot, the question is simply this: Is it worth the sum of $800 000, in addition to the $2 430 810 total for Mr. Morison's excellent dam, to place that structure beyond cavil or risk of any kind, and thus keep the total cost of that great structure at a figure but little more than one-third of the total cost of the less desirable type of dam proposed by the Commission?

Mr. Morison. GEORGE S. MORISON, Past-President, Am. Soc. C. E. (by letter).—In closing the discussion the writer feels that it is only right to express his gratification at the manner in which this paper has been received and the general tenor of the remarks which it has brought out.

The third plan was purposely put forward in the boldest form, with no provision to limit seepage, as it was the wish of the writer to have the dam considered on the assumption that no efforts were made to shut off the seepage of water in the permeable earth below. It was not so much his purpose to show what might be done as to raise the question of the measure of danger which would exist if nothing were done. While it is not good engineering to spend for any purpose a sum incommensurate with the results achieved, neither is it good engineering to neglect inexpensive methods which may be expected to reduce loss. In actual construction, the writer would expect to make use of simple methods which would be likely to reduce the flow of water through the permeable material in the bottom of the valley. Various plans suggest themselves. One would be to drive a diaphragm of iron or steel sheet-piling, which, with the aid of a water jet, could be driven to a very great depth, possibly to the underlying rock. The method proposed by Mr. Ford is original, and would prove effective when done, although the writer believes it would be necessary to resort to the use of compressed air, and, perhaps, even to the freezing process, and that its cost would be much greater than Mr. Ford has estimated. The method proposed by Mr. Duryea, of grouting the sand with a cement paste forced down through pipes under pressure, was considered by the writer, and he believes that it would prove both economical and effective; his present feeling is that he should use this device if he actually had to construct the dam. It was the aim of this paper, however, to show that, however desirable such additional protection might be, it was not really necessary, and that a dam could be built which would be absolutely safe and economically water-tight, without the use of any unusual methods, and which would require a minimum of skilled labor.

The particular form of dam adopted by Mr. Stearns for the North Dike, with the high rounded crest, which, while costing but little, gives additional security against waves breaking over the dam, is probably an improvement on the section adopted by the writer, but it would be much less important at Bohio than at Wachusett, simply because the location of the Bohio Dam at the end of a narrow waterway at some distance from the broad lake is one in which the waves are less likely to be violent. Mr. Stearns' studies and work in this connection are of a character which the engineering profession cannot appreciate too highly. Mr. Morison.

Mr. Campbell's calculation, giving a speed for the flow of water through the gravel and sand practically identical with that calculated by the writer, is, perhaps, a coincidence rather than more. In this calculation no account is taken of the difference in the coarseness of the materials, or of the distance through which the water must travel. In all probability the sand in his work was finer than the sand which the writer has estimated on, and the length through which the water must pass was probably considerably less, the two balancing each other.

The writer takes issue with the statements made by Mr. Burr, that "there is no basis for any prediction as to the existence of conditions which would make it even approximately accurate in this connection to use a formula derived from experiments in small filters, even though that formula be admirably adapted to all other filter conditions," and by Mr. Menocal that the formula "deduced by experiments by Mr. Allen Hazen, on filter beds with small heads and selected material, is not applicable to the conditions of this problem, as a small change in temperature or in the diameter of the sand grains would give widely divergent results, tending to check faith in the conclusions." It is perfectly true that Mr. Hazen's formula, like all other hydraulic formulas, is derived from experiments on a comparatively small scale. On the other hand, it is no less true that formulas which cannot be used to determine actual results can be safely used to determine maximum results. The writer has never contended that his calculations made with this formula were close indications of what the actual seepage would be. He does insist, however, that they show a maximum seepage, which maximum he believes to be many times what the actual seepage would prove. In this connection, the words of Professor Forchheimer are exactly to the point. His Table No. 8 shows the rapid reduction in the passage of water through unwashed sand as compared with clean sand of the same effective diameter, while his Table No. 9 shows velocities which are but a small fraction of that which the writer has estimated upon. The sand under the Chagres River is unwashed and undoubtedly mixed with much foreign matter; the sands analyzed by Mr. Hazen had all been washed by the water in which they were brought from the bore holes.

Mr. Morison. Fig. 17 shows the results of the borings made on or near the proposed dam site. That these borings show some irregularities is undoubtedly true, but they indicate that there is generally permeable material in the lowest part of the valley. The conditions under which a given cross-section would pass a maximum amount of water would occur when the position of that permeable material was perfectly regular so that it formed a straight and direct body of sand; the writer has assumed this material to be in such position. If, however, it is as Mr. Burr states, distributed "in the most irregular and irregularly limited strata or pockets," the difficulty which the water would meet in passing through would be aggravated by such irregularities, and the seepage would be reduced. The total length of borings shown in Fig. 17 below tide water is 6 075 ft., of which 816 ft. indicated permeable material. The total cross-section of the valley at Section *C* below tide water and above rock is 59 400 ft. If the permeable portion of this section bears the same relation to the whole that the permeable length of borings bears to the whole length of borings, this permeable section would be 7 960 sq. ft., or 40% of the 20 000 used in the calculations.

It must be remembered that under a given head the same amount of water will pass through 10 sq. ft. of sand, 5 ft. thick, as will pass through 100 sq. ft., 50 ft. thick. A thin diaphragm with a moderate number of holes placed in a large bed of sand would have comparatively little effect in reducing the flow through that sand; a thick diaphragm with the same area of holes would have a much greater effect. All the water which it is estimated would pass through this bed of sand, of 20 000 sq. ft. cross-section, 2 500 ft. long, would flow through a single orifice of less than 0.6 sq. ft. section in a thin plate. The actual thickness of the core-wall proposed for the Commission's dam, measured from out to out of sealing of cylinders, does not exceed 20 ft.; openings aggregating 160 sq. ft. of section, and filled with the same permeable material that is found under the river, would pass as much water as the whole 20 000 sq. ft., 2 500 ft. long. The total length of joints between caissons, below tide water, is 1 430 ft., and, as the cylinders have to be jointed to both caissons, the total length of joint is 2 860 ft.

Mr. Burr proposes to reduce his head for the pneumatic work by lowering the surface of the water from 30 to 40 ft. around the caissons, which he believes could be done with reasonable pump capacity. If this can be done, it is the best possible evidence that the seepage will not be serious. To reduce the water pressure, it is not only necessary to lower the water immediately around the caisson, but to take out enough water to reduce the head of saturation by 30 or 40 ft. Unless this is done, although the surface of the water may be lowered, the head of water against which atmospheric pressure must be provided will not be reduced. While the area of percolation immediately surrounding the pit would be small, it would increase

Mr. Morison.

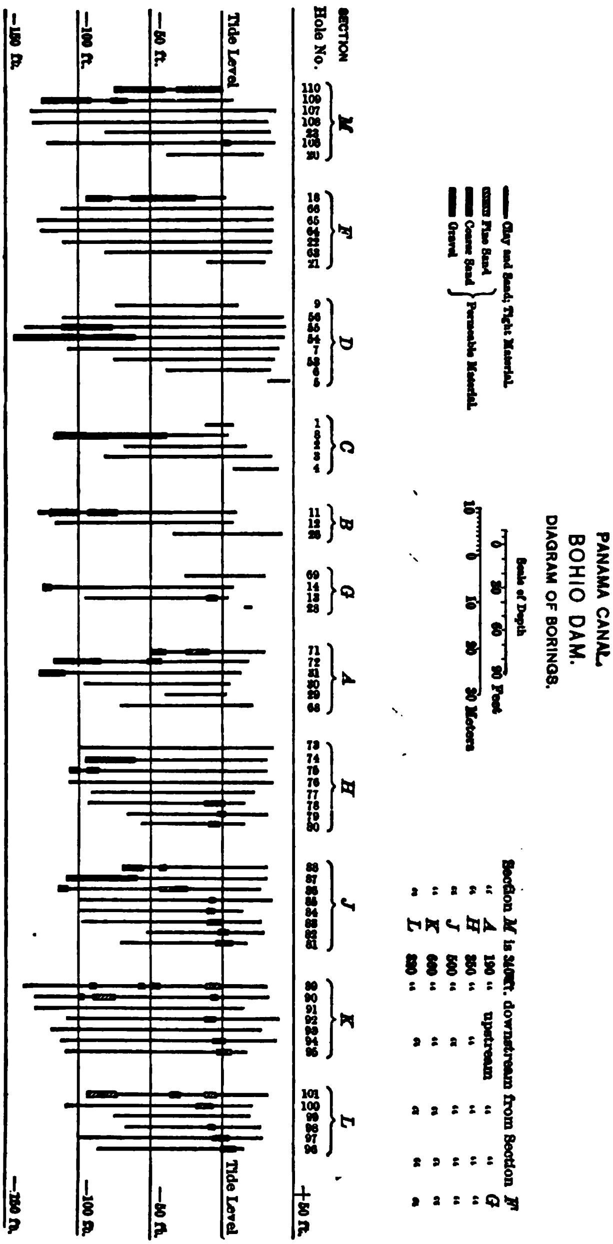

Fig. 17.